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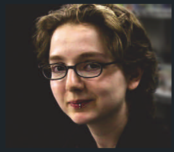

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ELECTRONIC COMPONENTS *solid state storage | MLC | SLC | speed | durability*

Separate the SSD myths from the facts.

Don't be deceived by tall tales. Get the facts about solid state drives (SSDs) from Toshiba, a leader in both hard disk drives (HDDs) and NAND flash technology. SSDs vs HDDs, MLC vs SLC, it's all about the right technology for the right application. Our high-capacity MLC NAND-based SSDs are proving to be a good fit for a growing number of today's mobile users, thanks to Toshiba performance advantages, reliability, and ruggedness. And that's no myth.

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To debunk 10 SSDs myths, log on to
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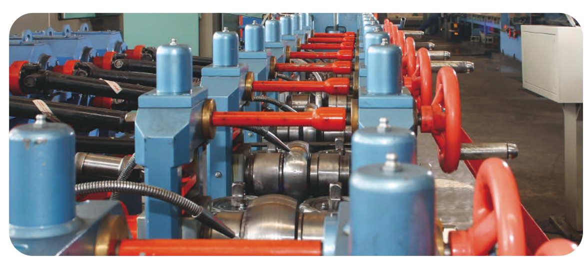

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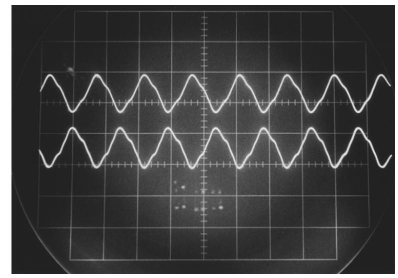

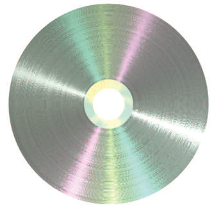

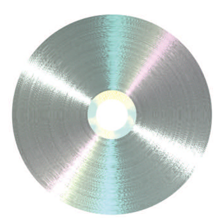

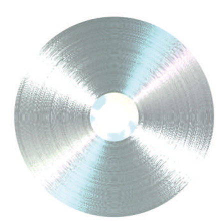

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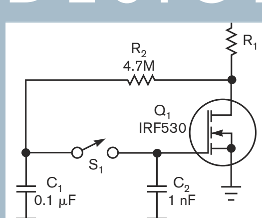

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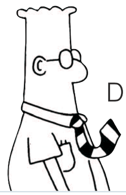

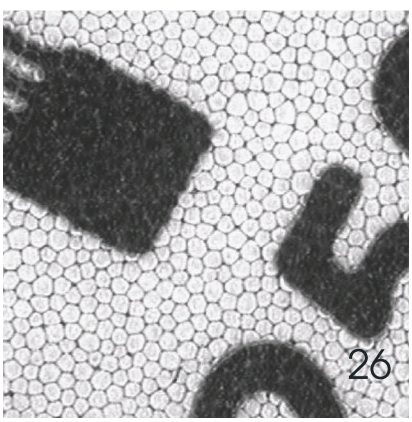

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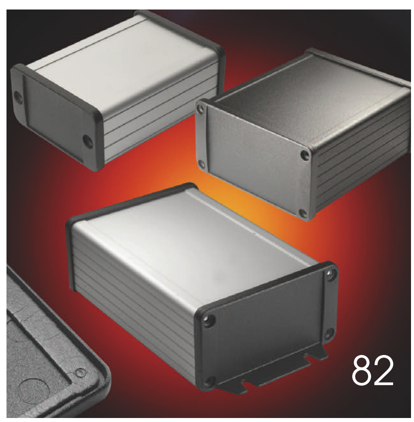

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DEPARTMENTS & COLUMNS

PRODUCT ROUNDUP

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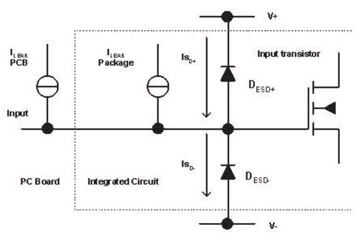

ONLINE ONLY

Check out these Web-exclusive articles:

Achieve femtoampere leakage in surface-mount op-amp layouts
Clever guardband techniques reduce leakage by 95%.
→www.edn.com/article/CA6579596

Periodic steady-state and small-signal analyses of switching regulators
Using analysis tools that quickly solve for steady-state conditions will work with PWM (pulse-width-modulation) switching regulators.
→www.edn.com/article/CA6579651

Designing battery-operated medical equipment for IEC 60601-1 compliance
The IEC (International Electrotechnical Commission) 60601-1 standard is a global benchmark for medical-device safety and provides general guidelines for hazard prevention in the design of battery-operated equipment.
→www.edn.com/article/CA6579335

VIDEO VIA INTERNET

EDN Senior Technical Editor—and award-winning blogger—Brian Dipert has been all over recent developments in Internet-video delivery, from Roku and VUDU to the Xbox and the PS3. Tune in to the recent post below, and be sure to follow the numerous links to Brian's past insights.

Sony's PlayStation 3 enters the ring
→www.edn.com/080807toc1

READERS' CHOICE

A selection of recent articles receiving high traffic on www.edn.com.

Sensor-rich designs
Designers are adding sensors and intelligent processing to fill the holes in their end-system capabilities, and it is yielding designs that cost less to produce and operate.
→www.edn.com/article/CA6574649

Designing a short-range RF link into a consumer-electronics product
Learn from the pitfalls and heartaches of a design team that started from scratch to integrate short-range RF into an iPod accessory.
→www.edn.com/article/CA6576137

Low-cost circuit incorporates mixing and amplifying functions
Using an amplifier with a power-down disable, you can combine the mixer and the amplifier functions.
→www.edn.com/article/CA6574651

Where is EDA going now?
Some important changes that have been altering the EDA landscape for years—in the geographic composition of the chip-design community and in the nature of the chip-design process—are now impossible to conceal.
→www.edn.com/article/CA6574655

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BY RICK NELSON, EDITOR-IN-CHIEF

Semicon West boosts solar power

Will synergies between the solar and the semiconductor industries help boost the use of solar power in North America? That scenario would seem to be a distinct possibility based on the turnout last month at Intersolar North America (www.intersolar.us), which took place, along with Semicon West (www.semiconwest.org), in San Francisco, on July 15 through 17. The reality is somewhat more complex, however.

According to Intersolar organizers, 12,000 visitors registered to attend the show, in which 210 exhibitors occupied the third floor of the Moscone Center West Hall—a relatively remote venue, compared with the more accessible and interconnected South and North halls. Despite the remoteness, Intersolar this year seemed to draw many more attendees than have the Semicon West test and production back-end exhibitors that for the past few years have occupied the West Hall upper-story exhibit space.

SEMI (Semiconductor Equipment and Materials International, www.semi.org), sponsor of Semicon West, took an early foray into the solar business last year when it invited Rhone Resch, president of the Solar Energy Industries Association (www.seia.org), to deliver a Semicon West keynote address, in which he urged attendees to get involved in the solar business. At least two traditional Semicon West exhibitors showed their support for solar this year by exhibiting in the Intersolar venue: Applied Materials showcased its technologies for creating high-efficiency photovoltaic solar panels, and KLA-Tencor highlighted its surface-metrology capabilities applicable to solar-power applications.

The international emphasis at Intersolar North America suggests that North America has missed a key opportunity to capitalize on solar power.

In my first visit to the Intersolar North America exhibit floor, the most eye-catching displays carried prominent banners reading "Germany" and "Austria"—representing the German Federal Ministry of Economics and Technology (www.bmwi.bund.de) and Austrian Trade (www.advantageaustria.org/us), respectively. That's not surprising, though, considering that Intersolar's organizer, Solar Promotion International GmbH, is based in Europe and that the governments of European countries, including Germany, offer incentives for deploying solar-power-generation capability.

Aaron Hand, executive editor for electronic media at *Semiconductor International* (www.semiconductor.net), offers more information (see "Thin-Film Photovoltaics Capture More of the Spectrum," *Semiconductor International*, July 1, 2008, www.semiconductor.net/article/CA6572785). He notes that the ultimate goal is lowering solar-module cost to $1 per watt, a price at which solar energy reaches "grid parity," when it can compete with fossil-fuel-generated power without government help.

The international emphasis at Intersolar North America suggests that North America has missed a key opportunity to capitalize on solar power, and, unfortunately, the situation is unlikely to improve, according to *EDN* Senior Editor Ann Steffora Mutschler, writing on the subject in her edn.com blog, "The Sandbox." She writes, "Given the poor state of the economy in the United States and with the situation likely to get worse for the semiconductor industry, companies supplying to customers outside the United States may have a better likelihood of business growth. Clearly, Germany leads the world in its acceptance and implementation of solar energy, although other big solar-supporting countries, such as Spain and Italy, are working hard to catch up, as evidenced by thin-film-solar-module-equipment supplier Applied Material Inc's many contracts in these geographies."

So, although solar-related opportunities might be there for US companies such as Applied Materials, those opportunities will most likely lie in supplying offshore customers. Perhaps the steep rise in fossil-fuel prices in the United States, relative to Europe, will alter the equation and promote the deployment of solar-generation capability in North America—with or without government help. EDN

Contact me at rnelson@reedbusiness.com.

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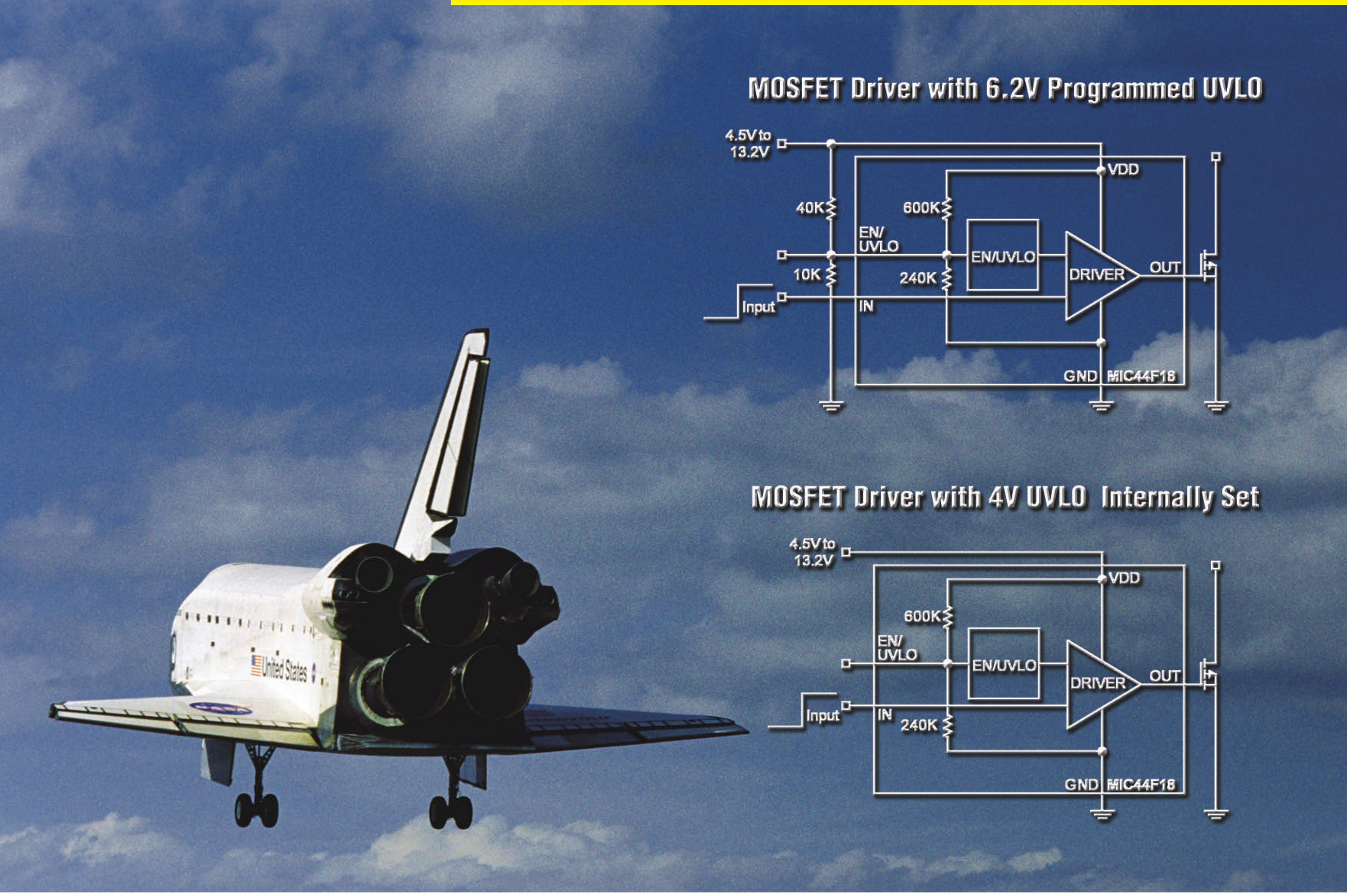
6A, 10ns Rise/Fall Times, Ultra High-Speed MOSFET Drivers



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Reed Electronics Group

EDITED BY FRAN GRANVILLE

pulse

INNOVATIONS & INNOVATORS

USB-powered battery charger goes faster, cooler, safer

The ubiquitous USB port is becoming an international power-source standard for consumer electronics because it eliminates concerns over differences in regional wall plugs, voltages, and frequencies. Targeting that market, Texas Instruments recently introduced its bq24150 USB switch-mode battery-charge-management IC. The device couples high power-conversion efficiency with fast charging and a reverse-boost USB OTG (On-The-Go) mode that generates a voltage supply to power accessories you plug into a mini-USB port, eliminating the need for another discrete device.

By adding a tiny, 1-μH inductor and small ceramic capacitors to the 3-MHz charger, which integrates 1.25A FETs, the charging circuit fits into 7.6×10.4 mm of PCB (printed-circuit-board) space. The device can achieve peak efficiency as high as 92% and supports a USB-battery-charging current as high as 900 mA. This current speeds the charging rate without exceeding the maximum 2.5W that the USB standard allows. The chip can handle an absolute-maximum input voltage of 20V and a maximum operating voltage of 6V, and it provides ±5% input-current-limit accuracy and ±0.5% voltage-regulation accuracy. You set the charge parameters using an I²C (inter-integrated-circuit)-communication interface. The chip features a safety timer with reset control and short-circuit, overvoltage, and thermal protection. The bq24150 charger comes in a 20-ball, 2×2-mm chip-scale package and sells for $2 (1000).**—by Margery Conner**

▷**Texas Instruments**, www.power.ti.com.

The bq24150 USB switch-mode battery-charge-management IC reaches a power-conversion efficiency of 92%.

FEEDBACK LOOP

"You don't need to have a community of road warriors to justify the need for much higher energy density than lithium ion. The market is already there, particularly in Japan. It is for cell phones with major video capability—that is, several hours per day. Japanese businessmen commute for hours and want extended video capabilities. The US market for the same product line—cell phone merging with portable PC—is not far behind."

—Reader H Frank Gibbard, in *EDN*'s Feedback Loop, at www.edn.com/article/CA6575574. Add your comments.

Miniature photocoupler features high-speed isolated switching

Toshiba Electronics Europe has launched the TLP117 miniature photocoupler for applications requiring a combination of isolation, high-speed data transfer, and low-power operation. The photocoupler integrates a high-speed gallium-aluminum-arsenide infrared LED and a high-gain, high-speed photodetector within a surface-mount, 4.4×3.6×2.5-mm MFSOP6 package. Maximum propagation delay is 20 nsec, yielding switching speeds of 50 Mbps. The device has an isolation-voltage rating of 3.75 kV and provides 2.5-times-faster isolated switching than previously available devices. The applications include logic systems in plasma-display panels, digital-home appliances, and high-speed factory-automation interfaces.

Operating with a 5V power supply, the device has a maximum current consumption of less than 5 mA. The photocoupler comes in an inverter-logic configuration with totem-pole output and provides an isolation voltage of 3750V rms. An internal shield ensures a minimum common-mode transient immunity of 10 kV/μsec. The device complies with all international safety approvals and operates over a temperature range of −40 to +105°C.

—by Graham Prophet

▷**Toshiba Electronics Europe**, www.toshiba-components.com.

Battery-operated, 6.2-GHz real-time spectrum analyzer incorporates DPX technology, GPS, and mapping

Tektronix describes its latest real-time spectrum analyzer, the $22,900, rechargeable-battery-operated, 10-kHz to 6.2-GHz SA2600, as a handheld instrument. King Kong might call it that, but few humans would. The company rejected characterizing the product as portable because, among spectrum analyzers, *portable* usually refers to much larger and heavier instruments. For many of these, the term *luggable* seems more appropriate, but even it doesn't fully convey the difficulty of moving them. Conversely, most people consider a handheld unit to be something that you can hold in one hand, but few people, if any, can hold a 10×13×4.8-in., 12.27-lb unit that way—at least not for long. However, with the aid of a sleeve that the manufacturer supplies, you can easily and comfortably slip the instrument over one forearm and operate the controls with your other hand.

The SA2600 incorporates the manufacturer's proprietary DPX digital-phosphor technology, which was heretofore unavailable in any spectrum analyzer smaller than a benchtop unit. DPX uses dedicated high-speed hardware to process more than 2500 measurements/sec and show you how spectra change in real time. According to a Tektronix spokesman, the instrument processes spectra in less than 1% of the time the fastest swept-frequency spectrum analyzer requires and provides 100% probability of intercept for transients with durations of at least 500 μsec. The SA2600 also provides 20-MHz real-time bandwidth and 153-dBm DANL (displayed average-noise level).

The company has also added DPX technology to another RF-measurement instrument of similar small size, the $38,900 H600 RF Hawk. Owners of older H600s can add the DPX capability to these instruments at no charge. The SA2600 and H600 incorporate GPS (global-positioning-system)-mapping tools that enable you to plot RF measurements on topographic maps without using separate GPS devices or PCs. You can view a video demonstration of DPX on the SA2600 at www.tek.com/RTSA/handheld. Click on Product Video.

—by Dan Strassberg

▷**Tektronix Inc**, www.tektronix.com.

The SA2600's color-graded DPX display rapidly shows you transient phenomena, such as the interfering signal in the blue trace, which you can observe changing as the interfering signal changes.

DILBERT By Scott Adams

08.07.08

10-GBPS LINKS SPAN 30m IN COPPER

According to fabless-telecom-chip-maker Phyworks, more than 80% of high-speed-data-center interconnections span less than 30m, and optical links over those distances have a heavy overhead in cost, space, and power. The company has taken the equalization and CDR (clock- and data-recovery) capabilities that it developed for optical-data systems and built its PHY2060 IC into active serial-copper-cable assemblies. The result is a complete 10-Gbps assembly that achieves error-free transmission at a latency of 120 nsec over 30m of 24-gauge AWG twinaxial copper cable.

The PHY2060 lets you hot-plug new copper-cable interconnects into existing optical ports and allows data centers to integrate the approach into XFP (10-Gbps-small-form-factor-pluggable) and emerging SFP+ (small-form-factor-pluggable) ports. The device's 10-Gbps inter-rack connections to 30m have traditionally depended on 10GBase-SR optical modules and 10GBase-CX4 copper cable. In the XFP connector format, a pair of 10GBase-SR optical modules costs $400 to $600; Phyworks expects a substitute active-serial-copper-cable assembly will cost $150 to $200. The cable itself is also less costly.—by Graham Prophet

▶**Phyworks**, www.phyworks-ic.com.

Clearer, Louder Audio Quality

Industry's first stereo audio, Class-D amp with DRC and AGC

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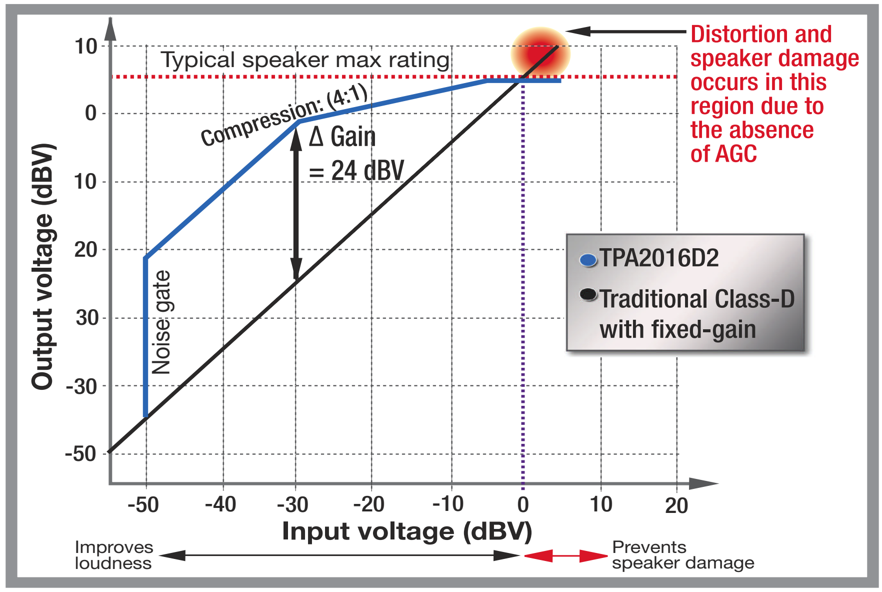

Applications

- Wireless handsets, smartphones
- Personal navigation devices
- Notebook PCs
- Portable DVD players, games, radios
- Educational toys

Features

- Output power: 1.7W/Ch into 8-Ω
- Highly programmable Dynamic Range Compression/Automatic Gain Control (DRC/AGC)
- Selectable gain from –28dB to +30dB in 1dB steps for flexible volume control
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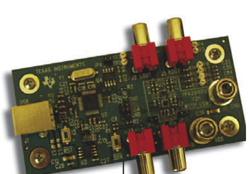

Ideal for portable applications, the **TPA2016D2** is an advanced stereo audio, Class-D amplifier. It delivers a 1.7W-per-channel output drive capability across an 8-Ω load and improves overall speaker volume compared to traditional Class-D devices. This amplifier features programmable dynamic range compression (DRC), which automatically adjusts audio levels to desired loudness ranges, protects speakers, and prevents clipping and distortion. In addition, flexible design parameters and intuitive support tools ease design and speed time-to-market.

Device	Output Power (W)	Power Supply (V) (min)	Power Supply (V) (max)	Load Impedance (Ω) (min)	PSSR (dB)	Package(s)	Price (1k)*
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TPA2013D1	2.7	1.8	5.5	4	95	QFN, WCSP	$1.45
TPA2012D2	2.1	2.5	5.5	4	75	QFN, WCSP	$0.95
TPA203xD1	2.75	2.5	5.5	4	75	WCSP	$0.60
TPA2010D1	2.5	2.5	5.5	4	75	WCSP	$0.55

** Suggested resale price in U.S. dollars in quantities of 1,000.*

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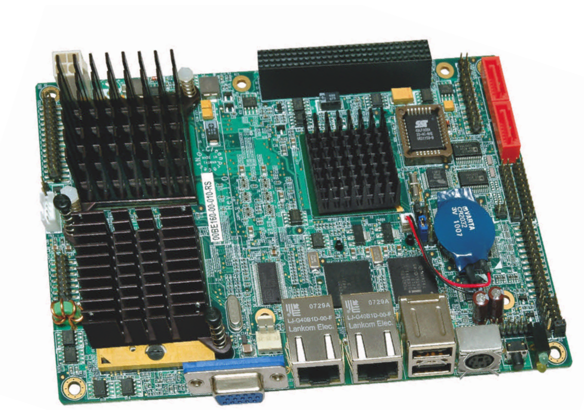
Embedded computer offers multicore performance

Targeting embedded-system applications, such as industrial automation, multimedia kiosks, gaming, and medical devices, Ampro Computers recently announced the ReadyBoard 830 single-board computer, which the company based on the EPIC (embedded-platform-for-industrial-computing) form factor. Featuring a 1.66-GHz Intel (www.intel.com) Core Duo L2400 or 1.07-GHz ULV Celeron processor, sockets for as much as 4 Gbytes of RAM, and a built-in Intel GMA950 graphics display, the ReadyBoard 830 can support CRTs, flat panels, and wide-screen digital TVs at resolutions as high as 2048×1536 pixels. The module also features a variety of I/O interfaces, including dual GbE (gigabit-Ethernet) ports, six USB 2.0 channels, AC (audio codec) 97/high-definition audio, multiple storage-device interfaces, a Compact Flash socket, four serial ports, eight general-purpose I/O pins, and a parallel port.

Expansion capability includes a PCIe (peripheral-component-interconnect express) Mini Card and a PCI-104 expansion bus. An optional MiniModule ISA (industry-standard-architecture) card provides a PCI-to-ISA bridge for compatibility with hundreds of commercial ISA-bus-based PC/104 cards. The 1.66-GHz dual-core processor uses less than 15W total power, and the 1.07-GHz single processor uses less than 5.5W. Ampro supports the ReadyBoard 830 with several embedded and desktop operating systems, including a Linux 2.6-based distribution, Windows Embedded CE 6.0, and Windows XP Embedded. Prices start at approximately $650 (production quantities).—**by Warren Webb**

▷**Ampro Computers**, www.ampro.com.



The ReadyBoard 830 integrates a single- or dual-core processor, RAM, graphics, networking, and extensive I/O into a small form factor suitable for high-performance embedded-system applications.

FEEDBACK LOOP

"Great article. I hope that marketing types will read this and not create the 'creeping-feature creature' that seems to pervade most new electronic products."

—Reader Wayne Vyrostek reveals what he thinks of "feature-itis." Read other comments and add your own in *EDN*'s Feedback Loop, at www.edn.com/article/CA6566540.

ASML BOOSTS IMMERSION-LITHOGRAPHY PERFORMANCE

Targeting 38-nm-memory and 32-nm-logic-semiconductor high-volume manufacturing, lithography giant ASML Holding NV recently introduced its Twinscan XT:1950i lithography system. The device uses a 1.35-numerical-aperture lens, which the company claims increases the performance of its immersion-chip-lithography systems 25% by improving overlay, resolution, and throughput. ASML claims that the XT:1950i is the industry's first single-exposure immersion-lithography system for high-volume manufacturing at 38 nm, which makes 10% more wafer area available for chips over the company's previous-generation tool, the Twinscan XT:1900i.

Along with more wafer area, the XT:1950i allows a productivity increase of almost 15% with its throughput of 148 wafers per hour. To keep up with Moore's Law in a timely and cost-effective manner, the semiconductor industry requires high-throughput immersion lithography, says Martin van den Brink, executive vice president of marketing and technology for ASML. According to van den Brink, a reduction in size boosts memory capacities and multimedia applications for DRAM and flash, and this reduction drives advanced integration and improved performance for logic applications, such as computer chips and DSPs for portable devices.

Also, to increase the performance of its Twinscan XT:1700i and XT:1900i immersion systems, ASML plans to make upgrade packages available beginning in the first quarter of 2009. These packages will improve overlay by 14 and 17% and productivity by 4 and 7%, respectively. The XT:1950i has a 30% tighter overlay-accuracy specification and nearly 15% better productivity than the XT:1900i. The new device also has 5% better resolution, resulting in a 10% area increase for higher yield, better performance, or both. The Twinscan XT:1950i provides a 3.5-nm overlay capacity. ASML expects to begin shipping the XT:1950i by the first quarter of 2009.

—by Ann Steffora Mutschler

▶**ASML Holding NV**, www.asml.com.

08.07.08

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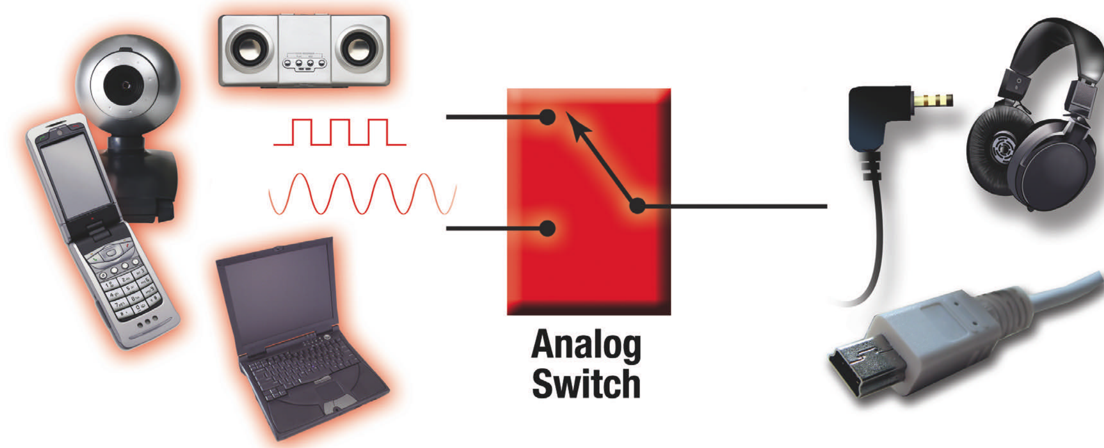

TI's newest **Analog Switch family (TS)** offers a variety of options including different ON resistances, bandwidth, charge injection and total harmonic distortion (THD). Our broad switch portfolio includes analog, specialty and digital switches designed to support applications such as audio and video data transmission. Optimize your next-generation portable communications, computing and consumer electronic designs using analog switches.

Device	Configuration	r_{ON} (max)	r_{ON} Flatness (max)	r_{ON} Mismatch (max)	V+(V) (min)	V+(V) (max)	ESD	ON Time (ns) (max)	OFF Time (ns) (max)	Package
TS5A23166	SPST x 2	0.9	0.25	0.1	1.65	5.5	2 kV HBM	7.5	11	US8-8, WCSP-8
TS3A4751	SPST x 4	0.9	0.4	0.05	1.65	3.6	4 kV HBM	14	9	TSSOP-14, **SON-14, µQFN-14**
TS5A6542	SPDT	0.75	0.25	0.25	2.25	5.5	15 kV Contact (IEC L-4)	25	20	WCSP-8, µQFN-8
TS5A3159A	SPDT	0.9	0.25	0.1	1.65	5.5	2 kV HBM	30	20	SC70-6, SOT23-6, WCSP-6
TS5A12301E	SPDT	0.75	0.1	0.1	2.25	5.5	8 kV Contact (IEC L-4)	225	215	WCSP-6
TS5A23159	SPDT x 2	0.9	0.25	0.1	1.65	5.5	2 kV HBM	13	8	MSOP-10, QFN-10
TS3A24159	SPDT x 2	0.3	0.04	0.05	1.65	3.6	2 kV HBM	35	25	WCSP-10, SON-10, VSSOP-10
TS5A26542	SPDT x 2	0.75	0.25	0.25	2.25	5.5	15 kV Contact (IEC L-4)	25	20	WCSP-12
TS5A22362/4	SPDT x 2	0.94	0.46	0.11	2.3	5.5	2.5 kV HBM	80	70	WCSP-12, SON-10, VSSOP-10
TS3USB221	SPDT x 2	6	1	0.2	2.3	3.6	2 kV HBM	30	12	SON-10, µQFN-10
TS3A44159	SPDT x 4	0.45	0.1	0.07	1.65	4.3	2 kV HBM	23	32	TSSOP-16, SON-16, µQFN-16
TS5A3359	SP3T	0.9	0.25	0.1	1.65	5.5	2 kV HBM	21	10.5	US8-8, WCSP-8
TS3A5017	SP4T x 2	12	9	2	2.3	3.6	2 kV HBM	9.5	3.5	TVSOP-16, SON-16, **µQFN-16**

Red text denotes new products and new package addition

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Get samples, datasheets and order the new Analog Switch Guide

Texas Instruments

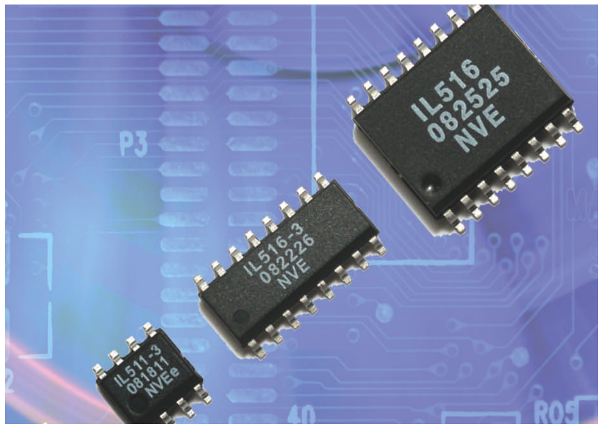
Digital isolators reach 2 Mbps, pack in as many as four channels

Using optocouplers is a common, inexpensive method of signal isolation, but your application may be unable to tolerate optocouplers' tendency to degrade with age and temperature. Targeting that problem, NVE has introduced the IsoLoop IL500 series of nonoptical digital isolators that operate as fast as 2 Mbps. The parts feature a patented, controllable refresh clock to ensure I/O synchronization within 9 μsec; some models in the series allow the use of an external synchronization clock. Maximum propagation delay is 25 nsec, and pulse-width distortion is 10 nsec.

The series is available in one-, two-, three-, and four-channel models; the one- and two-channel models are available in either SOIC packages or eight-pin MSOPs. The three- and four-channel models are available in 0.15- or 0.3-in.-wide, 16-pin SOIC packages. All NVE products are available in ROHS (restriction-of-hazardous-substances)-directive-compliant, lead-free versions. The isolators operate over a supply-voltage range of 3 to 5.5V and a temperature range of −40 to +85°C. Typical transient immunity is 30 kV/μsec. The parts are UL (Underwriters Laboratories) 1577-approved, and IEC (International Electrotechnical Commission) 61010-2001 approval is pending. Prices start at 53 cents (1000) per channel.

—by Margery Conner

▷**NVE Corp**, www.isoloop.com.



The IsoLoop IL500 series of digital isolators packs in as many as four channels and operates as fast as 2 Mbps.

FPGA START-UP AIMS AT ASIC MARKET

08.07.08

FPGA newcomer SiliconBlue is targeting the market for ASIC replacement for portable, battery-powered devices. The iCE product is a conventional FPGA architecture—a look-up-table structure. Exploiting the features of the low-power variants of today's 65-nm CMOS processes, the company can now build an FPGA with on-chip nonvolatile memory that has low static- and dynamic-power consumption without requiring special low-power modes.

For more on the architecture, go to www.edn-europe.com/fpgastartupchallengesinlowpowersector+article+2228+Europe.

—by Graham Prophet

▶**SiliconBlue**, www.siliconbluetech.com.

Broadband low-noise amplifier provides mobile-TV reception from VHF to L band

Infineon Technologies has released the BGA728L7 broadband low-noise amplifier for portable- and mobile-TV applications. The BGA728L7 covers the VHF (very-high-frequency) III, UHF (ultrahigh-frequency), and L bands. It offers high- and low-gain modes. In high-gain mode, the BGA728L7 helps to improve reception sensitivity for weak signals through its noise figure of 1.4 dB and 16-dB gain. For a strong input signal, you can switch the BGA728L7 to low-gain mode to offer higher linearity with current consumption of 0.5 mA.

The main challenges for mobile-TV systems are to achieve high dynamic range, to enhance system sensitivity for indoor reception or tunnels, and to fulfill the stringent MBRAI (multi-basic-rate-interface) requirements. The amplifier supports various standards, such as DVB-T (digital-video broadcast-terrestrial), DVB-H (digital-video broadcast-handheld), ISDB-T (integrated-services digital broadcast-terrestrial), MediaFlo, and T-DMB (terrestrial digital-multimedia broadcasting), as well as the emerging Chinese standards, including CMMB (China mobile-multimedia broadcasting), TMMB (telecommunication-mobile-multimedia broadcasting), and DMB-TH (digital-multimedia broadcast-terrestrial/handheld). The switching time of 3.5 μsec allows the amplifier to support time-slicing-based mobile-TV systems.

The BGA728L7 supports a supply-voltage range of 1.5 to 3.6V. Due to the low-voltage and -current capabilities, the amplifier allows higher energy efficiency for portable devices and extends their battery-usage time. The on-chip 1kV HBM (human-body-model) ESD (electrostatic-discharge) protection simplifies the system's ESD-protection effort and makes the amplifier resistant to ESD events during assembly. The broadband amplifier integrates a high-performance silicon-germanium bipolar transistor and active-biasing, feedback, and I/O-matching circuits. It needs three external passive components, and you can use it to quickly build a compact, low-power mobile-TV design.

—by Graham Prophet

▷**Infineon Technologies**, www.infineon.com.

VOICES

15 steps to starting your own electronic-kit business

After Limor Fried received her master's degree in computer science and electrical engineering from the Massachusetts Institute of Technology in 2004, she started her own business designing and selling electronic kits, targeting customers who want to explore embedded-microcontroller-based designs or create their own GPS (global-positioning-system)-based systems, among others. She has made Adafruit Industries into a successful electronics-kit business, and, based on her own experience, offers these 15 practical steps for engineers who dream of starting their own kit business.

Fried based her rules on the following assumptions: First, there is only one of you. Multiple people in a business make everything far too complex. Second, these rules assume that you have a job and can provide your own seed capital. Third, you are computer-literate, and the Internet doesn't scare you. If those assumptions about you are correct, read on for the rules.

1 You need expertise, a skill, or an interest that you can parlay into a product, such as designing the hardware for a GPS unit.

2 Think of a memorable name for your company.

3 Register a domain name based on your company name, including the .net and .org versions, as well as the .com. Then file a DBA (doing-business-as) document. Open a bank account and get a credit card under your DBA name.

4 Get a digital camera and start learning how to take good pictures of your projects, which will ultimately become your products.

5 Get two to four projects under your belt. Purchase all the parts on the business bank account, which makes your accounting much easier than if you rely on stuffing receipts into a box. This step can take two to 12 months.

6 Take photos of your projects, which are now your products. These photos are important to communicate to your audience what you and your projects are all about. Be prepared to spend hours learning what makes a good product photo and how to take it. Use video if that's what it takes to communicate your products' features and capabilities. Come up with a "money shot," the one photo that perfectly explains your project. Don't just take a picture of a PCB (printed-circuit board); take a picture of what the project allows you to do—for example, can you use it to put on a light show?

7 Put basic documentation of your project online. You can use the Wordpress.com or the instructables.com site. Put the picture at the top of the project page. Below that, place a one-paragraph description of the project with specifications. For example, if you built a DMX-controlled RGB LED light, your paragraph should describe how bright it is, the DMX-control functions, how many LEDs it has, and why it's innovative. People who will give you publicity are busy, and you should make it as easy as possible for them to copy and paste your photo and description to their blog posts. Repeat this step for each project.

8 Fill out the rest of your Web site with information about yourself to give visitors a sense of who you are. Include your e-mail address with a comment, "If you're interested in purchasing one of my products, drop me a line."

9 Now, you're ready to look for traffic to your site. Send a short e-mail with a link to your site and a two-sentence description to blog authors who would be interested, such as those at www.makezine.com. Also, post to forums for your type of do-it-yourself projects and kits, but don't spam them.

10 Look at your Web-site statistics and read all your comments from visitors. Find out what interests them.

11 Find a project that is easy to sell or re-create. Figure out what it would cost to make 100 units, based on the best component pricing. Allow for a 40% profit, or a markup of approximately 66%. Now, add the markup again. This total is your retail cost. So, if your project costs \$10 in parts, its wholesale price would be \$16.50, and its retail price would be \$27.50. A \$25 to \$75 retail-price range for your projects is a good one to start with.

12 Buy enough parts to make 25 projects or kits. Put PayPal "buy-now" buttons on the project's Web page. Decide whether you want to sell internationally; it's more expensive, but it opens up your market.

13 Create a support network for your new customers by creating a forum or mailing list. Answer customers' questions only once; then, place them into the frequently asked questions section or documentation. Because you've added that 40% retail margin, you can now look for some resale outlets.

14 Repeat and refine steps 6 through 12. Try to release a new project every few months. Focus on improving your designs and your business flow. As you expand, you'll be able to look into hiring help, upgrading your bookkeeping, and buying equipment. But always keep an eye on your …

15 Profit!

—by Margery Conner

BY BONNIE BAKER

The eyes of the electronic world are watching

Silicon photo sensors have been in electronic circuits since the inception of the era of silicon electronics. More than likely, scientists quickly discovered the photo-sensing characteristics of silicon in the lab, as they worked from the daylight hours into the evening. To this day, IC designers regularly cover their wafers under test to shield out extraneous light. Although the light sensitivity of silicon is an undesirable by-product of the silicon, system designers have exploited this transfer of light into electrical energy in various systems. Consequently, a wide variety of applications use silicon to sense the intensity and characteristics of light.

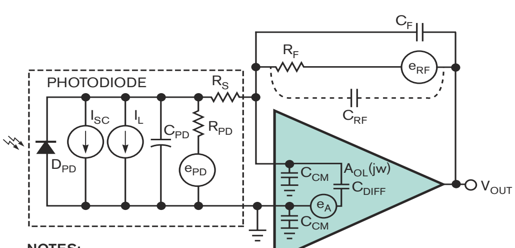
In these systems, a silicon sensor converts light into charge or an electrical current. These silicon sensors are the "eyes" in the electronics world that users can employ to analyze blood, search noninvasively for tumors, detect smoke, position equipment, or perform chromatography, to name a few applications. Basically, system designers understand how to convert light into a current, but the real challenge is determining how to convert the low-level currents from the photo sensor into a useful electrical representation. To further exacerbate the difficulty of the design, the required accuracy in these applications continues to increase.

The traditional design topology of the transimpedance amplifier captures this low-level signal in a hybrid approach that starts with an amplifier and a high-value resistor in the feedback loop. The circuit design uses resistance to provide a real-time, linear representation of the light source. This circuit places the photodiode across the amplifier's inverting input and ground of the operational amplifier. A resistor with a value of 100 kΩ to 10 MΩ connects the inverting input of the amplifier to the output. You then connect the noninverting input to ground (**Figure 1**). Light excitement on the photo sensor generates charge. The only path of escape for this charge is through the high-value resistor in the amplifier's feedback loop.

The simplistic approach in **Figure 1** is not without its design challenges. The operational amplifier must have relatively low-picoampere input-bias currents and low input capacitance. An appropriate amplifier for this circuit would have a FET- or a CMOS-input stage with low-voltage noise and microvolt-offset specifications. In the end, the designer optimizes the stability, bandwidth, low-noise performance, and layout of this transimpedance-amplifier circuit.

The final design method is not always intuitively obvious. The photo sensor, operational amplifier, amplifier-feedback element, and these parts' parasitics combine to create quite a rat's nest of formulas for consideration. The signal after the transimpedance amplifier requires a multipole analog filter. In this manner, combining the input and filtering stages separates the signal of interest from the noise floor. A sampling ADC digitizes the signal after the analog filter.

Photo-sensing circuits have changed over the years. The first approach was purely analog, using the transimpedance amplifier and following it with a lowpass filter. From the classic transimpedance amplifier, the switched integrator has gained favor. The switched integrator was the first step toward bringing the digital portion of the circuit closer to the signal source. The migration of the photo-sensing-application product has moved on to totally integrated systems, such as the charged digitizing ADC. **EDN**



NOTES:
D_{PD}=IDEAL PHOTODIODE.
I_{SC}=CURRENT GENERATED BY LIGHT.
I_L=LEAKAGE CURRENT.
C_{PD}=DEVICE CAPACITANCE.
e_{PD}=DEVICE-VOLTAGE NOISE.
R_{PD}=DEVICE PARALLEL RESISTANCE.
R_S=DEVICE LEAD RESISTANCE.
C_F=FEEDBACK CAPACITOR.
R_F=FEEDBACK RESISTOR.
C_{RF}=FEEDBACK-RESISTOR PARASITIC CAPACITANCE.
e_{RF}, e_A=RESISTOR- AND AMPLIFIER-VOLTAGE NOISE.
C_{CM}=COMMON-MODE-AMPLIFIER CAPACITANCE.
C_{DIFF}=DIFFERENTIAL-AMPLIFIER CAPACITANCE.
A_{OL}(jw)=AMPLIFIER OPEN-LOOP GAIN.

Figure 1 A transimpedance photo-sensing circuit is not without its design challenges.

Bonnie Baker is a senior applications engineer at Texas Instruments and author of A Baker's Dozen: Real Analog Solutions for Digital Designers. *You can reach her at bonnie@ti.com.*

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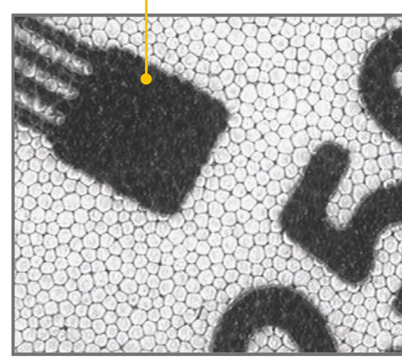
Revisiting electronic ink

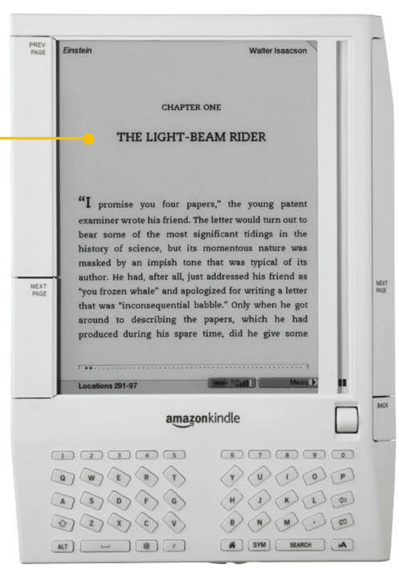
ELECTRONIC INK HAS CHANGED IN THE SEVEN YEARS SINCE WE LAST TOOK A LOOK AT IT.

When *EDN* looked at electronic ink seven years ago, there were two visible commercial approaches to delivering display information. E Ink's (www.eink.com) approach has made the larger visible move from the lab to product within the last three years as a display technology; however, the underlying approach has changed somewhat. The approach remains fundamentally the same except that the millions of microcapsules, with a 50-micron diameter arranged in a honeycomb structure, now hold a clear fluid instead of a colored oil, and it employs a two-pigment particle method instead of a single-pigment particle method suspended in the fluid to display information.

The electronic-ink film consists of millions of microcapsules arranged in a honeycomblike structure. When you magnify the structure, you can see the microcapsules and how the pigment fragments do not have to align on a one-to-one basis with the microcapsules to form images. The addressing backplane rather than the size of the microcapsules limits the dot-per-inch resolution.

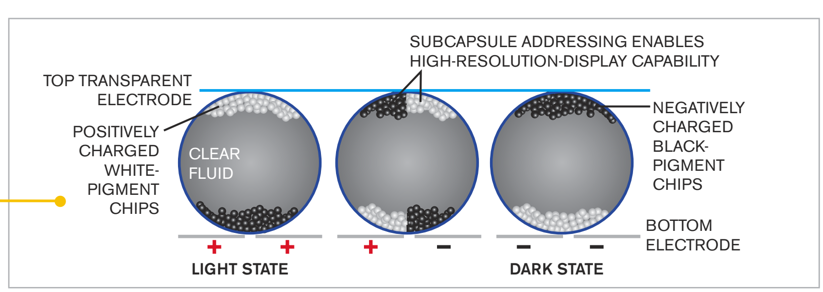


Electronic ink has moved into the e-book market. Although the electronic-ink film is flexible, current e-books are implementing a rigid display with a glass cover for physical protection and as many as seven layers of coating for ultraviolet protection of the display.



Electronic ink supports small and low-power displays, such as for USB flash disks and wrist watches.

The pigment fragments within each microcapsule move independently based on the polarity of the charge on the addressing electrodes that sandwich the electronic-ink film. Higher voltages, such as 15V on the electrodes, result in faster movement of the pigment fragments for refresh rates of 250 msec. Lower voltages would require slower refresh rates to allow the pigment fragments to fully shuttle through the microcapsule fluid. When the addressing electrodes are powered off, the pigment fragments maintain their position within the microcapsule for up to a year without consuming any more power in the system.

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Free software ENCIRCLES EMBEDDED DESIGN

BY WARREN WEBB • TECHNICAL EDITOR

OPEN-SOURCE SOFTWARE HAS BECOME A STAPLE IN THE EMBEDDED-SYSTEM INDUSTRY AS DESIGNERS STRUGGLE WITH ESCALATING SOFTWARE COMPLEXITY ON LIMITED BUDGETS.

With potentially huge savings on operating software, development tools, recurring royalties, and schedules, designers and managers must at least consider open-source software on each new embedded-system project. A wide variety of open-source software has gained a foothold just as the embedded-system industry moves from limited-resource designs to high-performance systems with complex applications that may require new software functions, such as high-speed networking, wireless communications, interactive graphics, and data encryption. Developers can save thousands of man-hours of development costs by integrating freely downloadable operating systems, libraries, and components with their application-specific custom software.

Designers can choose from a variety of open-source-software components ranging from multiple variations of the wildly popular Linux operating system to sophisticated debugging tools. SourceForge.net, the largest open-source-software-development site, provides free hosting to more than 180,000 registered projects, including database, security, gaming, clustering, multimedia, and VOIP (voice over Internet Protocol) offerings. Before you jump on the bandwagon and start downloading free code, however, take a close look at the open-source characteristics that make it popular and the problems that designers cite as reasons to stay away. Customization, support, licensing, fragmentation, hardware costs, development tools, and real-time performance are just a few of the issues

AT A GLANCE

- Design teams that traditionally develop embedded software in-house are turning to open-source software to deal with increasing device complexity.
- Free source code and the lack of recurring royalties persuade many designers to consider open-source software on new embedded-system projects.
- You can scale several open-source-software offerings to fit the small-footprint-hardware configurations of embedded devices.
- Embedded-system developers have created multiple techniques to protect proprietary software and take advantage of open-source software.

that can influence your decision.

The initial task for embedded-open-source-software users is to adapt the code to work with a specific hardware configuration. By their nature, open-source products must fit the widest array of users, so they require generalization and do not target one application. This generalization can force designers to increase the memory system, and, unless the lack of royalties offsets it, this extra memory requirement translates into a higher recurring cost for the embedded device. Most commercial off-the-shelf board vendors now offer preconfigured open-source board-support packages for their products. For example, WinSystems provides a customized open-source-development kit with its off-the-shelf board-level products, which includes device-specific drivers, documentation, cables, and a quick-start guide (**Figure 1**). The kit also includes Blue Collar Linux, a basic embedded implementation of the Linux operating system that you can re-create from open-source files without special or proprietary development tools.

FIX MY CODE

The biggest complaint among potential open-source-software users is the lack of a central resource to provide support similar to that from a commercial-software vendor. Developers can often find answers to their questions through the Internet, but no one is on the hook to research and respond to questions. The alternatives are to develop an in-house support team or to contract with a third party. Although many in the industry widely perceive open-source software as free code, many designers are willing to pay for expert support, specialized tools, customization services, and prepackaged configurations to ease the development process. Commercial vendors have responded with custom embedded configurations, subscription-support packages, development-tool kits, and sample applications to augment the free code. For example, MontaVista Software offers contract-support services for embedded-Linux users on a subscription basis.

Another danger that developers see in the embedded-open-source-software environment is the potential for code fragmentation. If one developer decides to patch the open-source code to solve an integration problem and another developer makes a similar but incompatible modification, there are now three versions of the code. Applications a developer writes for one version may then be incompatible with the others. Because vendors usually ship the operating system along with the application in embedded devices, fragmentation is more of a concern to developers than to end users. Other than with specialty versions, such as real-time Linux, the Linux-open-source community has been successful in preventing the existence of multiple versions through an elaborate system of upgrade proposals and releases.

In general, open-source software is not in the public domain, and you must adhere to the rules that individual licenses set forth as a condition for use. The OSI (Open Source Initiative) maintains the complete text for more than 20 open-source-standard licenses that serve the community. As an example, Linux is licensed under the popular GNU GPL (general-public license) with detailed requirements for its use. If you modify and distribute GPL software, your modifications automatically fall under the GPL, and you must give the source code to

Figure 1 WinSystems provides an open-source-development kit with its board-level products that includes drivers, documentation, and an embedded implementation of Linux.

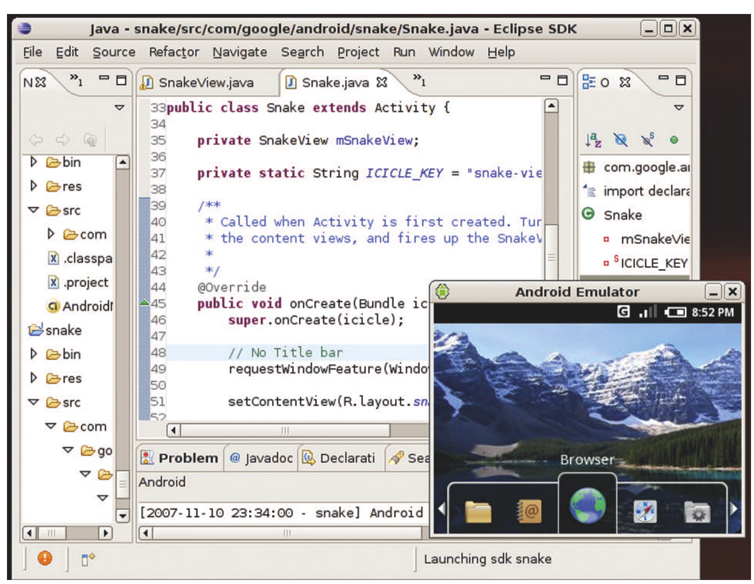
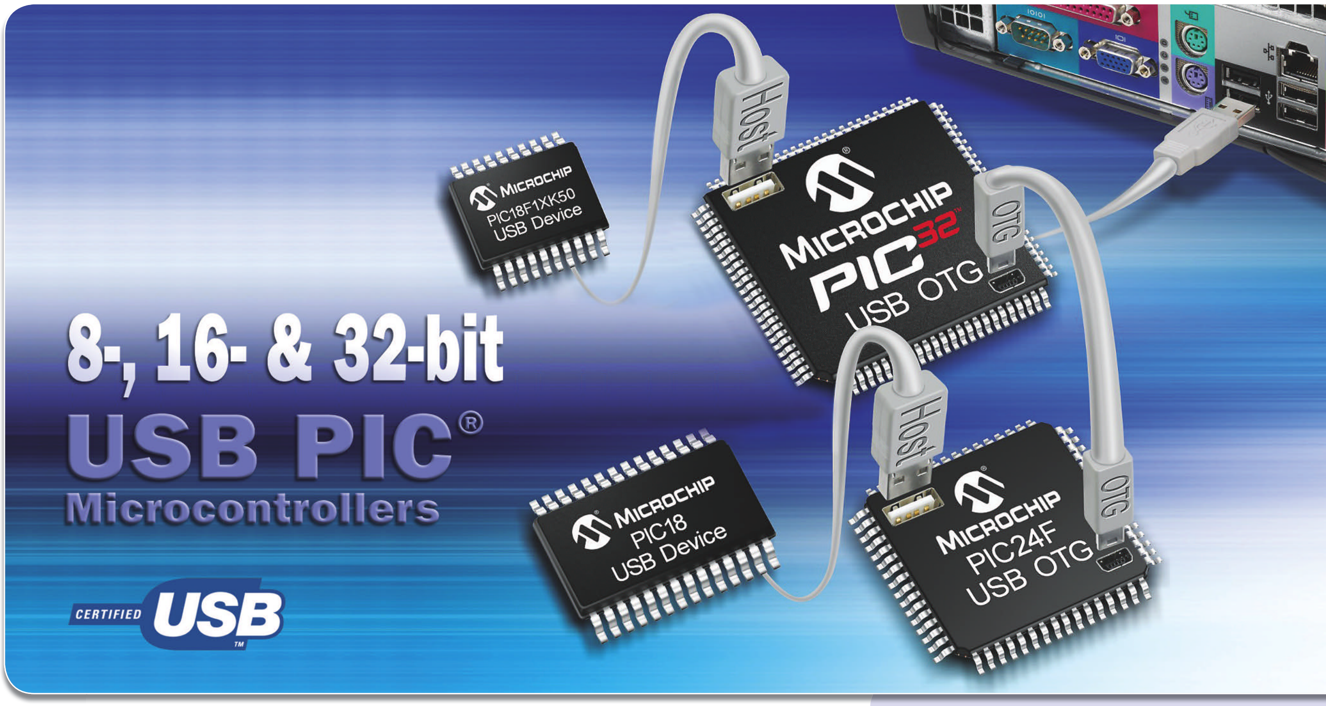


Figure 2 The Google Android software-developer kit provides the tools and APIs necessary to develop applications using Java.

USB Connectivity for Embedded Designs



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Core	Flash Program Memory	Pins	USB Type
8-bit	Up to 128 Kbytes	20 - 80	Device
16-bit	Up to 256 Kbytes	64 - 100	Device, Embedded Host, Dual Role, OTG
32-bit	Up to 512 Kbytes	64 - 100	Device, Embedded Host, Dual Role, OTG

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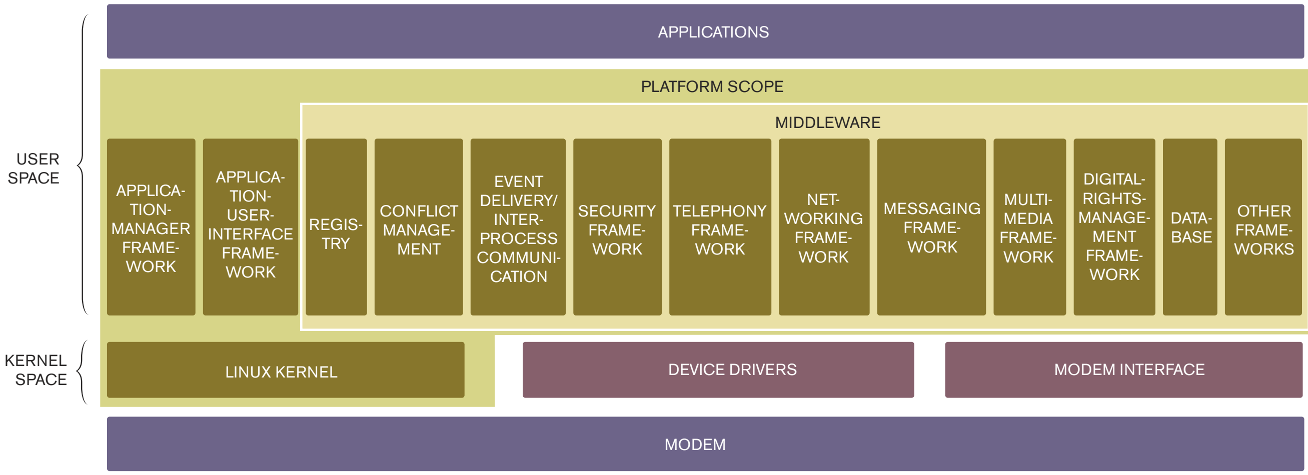

Figure 3 The Linux Mobile Foundation promises to deliver an open, hardware-independent software architecture for tomorrow's mobile devices.

anyone who asks for it. Although many embedded-system developers shy away from Linux because they worry that they may have to reveal the source code to their proprietary software, your application programs and device drivers may remain private as long as they are separate and distinct from the Linux kernel and contain no GPL code. This code isolation is a constant source of anxiety among developers, especially those who develop small-footprint embedded systems in which all software links together in a single ROM image. Even with these restrictions, you can download a free copy of Linux, adapt it to your product, and sell as many copies as you want without paying royalties.

FREE TOOLS

Development tools, such as the GNU-compiler collection and the GNU debugger, support most open-source-software packages. These tools are adequate

Analog Applications Journal

DESIGN BRIEF

Understanding Output Voltage Limitations of DC/DC Buck Converters

By John Tucker
Applications Engineer

Featured in the latest online issue

- Understanding the pen-interrupt operation of touch-screen controllers
- Understanding output voltage limitations of DC/DC buck converters
- Battery-charger front-end IC improves charging-system safety
- Using the CC2430 and TIMAC with low-power wireless sensors: A power-consumption study
- Selecting antennas for low-power wireless applications
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Introduction

Product datasheets for DC/DC converters typically show an operating range for input and output voltages. These operating ranges may be broad and in some cases may overlap. It is usually not possible to derive any arbitrary output voltage from the entire range of permissible input voltages. There are several factors that can cause this, including the internal reference voltage, the minimum controllable ON time, and the maximum duty-cycle constraints.

Ideal Buck-Converter Operation

Consider the theoretical, ideal buck converter shown in Figure 1. The buck converter is used to generate a lower output voltage from a higher DC input voltage.

If the losses in the switch and catch diode are ignored, then the duty cycle, or the ratio of ON time to the total period, of the converter can be expressed as

$$D = \frac{V_{OUT}}{V_{IN}}. \tag{1}$$

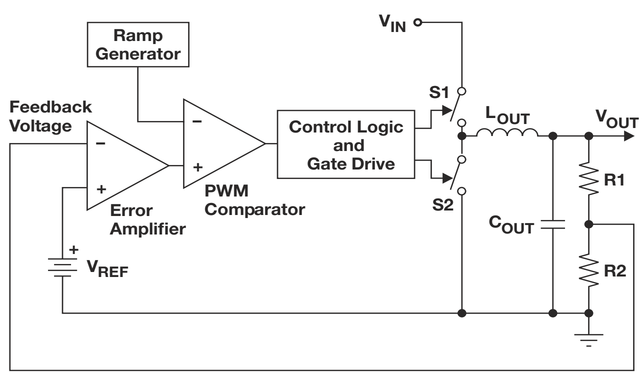

Figure 1. Theoretical, ideal buck converter.

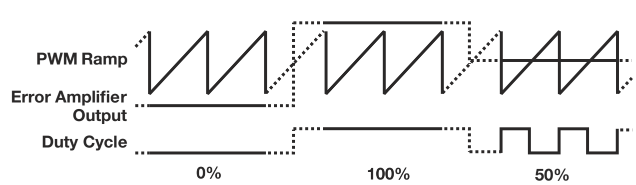

Figure 2. Typical PWM waveforms.

The duty cycle is determined by the output of the error amplifier and the PWM ramp voltage as shown in Figure 2. The ON time starts on the falling edge of the PWM ramp voltage and stops when the ramp voltage equals the output voltage of the error amplifier. The output of the error amplifier in turn is set so that the feedback portion of the output voltage is equal to the internal reference voltage. This closed-loop feedback system causes the output voltage to regulate at the desired level. If the output of the error amplifier falls below the PWM ramp minimum, then a 0% duty cycle is commanded, the converter will not switch, and the output voltage is 0 V. If the error-amplifier output is above the PWM ramp peak, then the commanded duty cycle is 100% and the output voltage is equal to the input

voltage. For error-amplifier outputs between these two extremes, the output voltage will regulate to

$$V_{OUT} = D \times V_{IN}. \tag{2}$$

Practical Limitations

For the ideal buck converter, any output voltage from 0 V to V_{IN} may be obtained. In actual DC/DC converter circuits, there are practical limitations. It has been shown that the output voltage is proportional to the duty cycle and input voltage. Given a particular input voltage, there are limitations that prevent the duty cycle from covering the entire range from 0 to 100%. Most obvious is the internal reference voltage, V_{REF}. Normally, a resistor divider network as shown in Figure 1 is used to feed back a portion of the output voltage to the inverting terminal of the error amplifier. This voltage is compared to V_{REF}; and, during steady-state regulation, the error-amplifier output will not go below the voltage required to maintain the feedback voltage equal to V_{REF}. So the output voltage will be

$$V_{OUT} = V_{REF}\left(\frac{R1}{R2} + 1\right). \tag{3}$$

As R2 approaches infinity, the output voltage goes to V_{REF} so that the output cannot be regulated to below the reference voltage.

There may also be constraints on the minimum controllable ON time. This may be caused by limitations in the gate-drive circuitry or by intentional delays. This minimum controllable ON time puts an additional constraint on the minimum achievable V_{OUT}:

$$V_{OUT(min)} = t_{on(min)} \times V_{IN} \times f_s, \tag{4}$$

where $t_{on(min)}$ is the minimum controllable ON time and f_s is the switching frequency.

The duty cycle may also be constrained at the upper end. In many converters, a dead time is required to charge the high-side switching FET gate-drive circuit. Feedforward circuitry may also cause a flattening of the PWM ramp waveform as the slope of the PWM ramp is increased while the period remains constant. This will limit the maximum output voltage with respect to V_{IN}. Typically, if there is a maximum duty-cycle limit, it will be expressed as a percentage, and the maximum output voltage will be

$$V_{OUT(max)} = V_{IN} \times D_{max}. \tag{5}$$

Effect of Circuit Losses

So far we have assumed that the components in the circuit are ideal and lossless. Of course, this is not the case. There are conduction losses associated with the components that are important in determining the minimum and maximum achievable output voltage. Most important of these are the ON resistance of the high- and low-side switch elements, and the series resistance of the output inductor. Taking these losses into account, we can now express the duty cycle of the converter as

$$D = \frac{V_{OUT} + I_{OUT} \times (r_{DS2} + R_L)}{V_{IN} - I_{OUT} \times (r_{DS1} - r_{DS2})}, \tag{6}$$

where r_{DS1} is the ON resistance of the high-side switch, S1; r_{DS2} is the ON resistance of the low-side switch, S2; and R_L is the output-inductor series resistance. Since the loss terms are added to the numerator and subtracted from the denominator, the duty cycle increases with increasing load current relative to the ideal duty cycle. This has the effect of increasing the available minimum voltage. The worst-case situation for determining the minimum available output voltage occurs when the input voltage is at its maximum specification, the output current is at the minimum load specification, and the switching frequency is at its maximum value. The minimum output voltage is then

$$\begin{aligned} V_{OUT(min)} = {} & t_{on(min)} \times f_{s(max)} \times [V_{IN(max)} - I_{OUT(min)} \\ & \times (r_{DS1} - r_{DS2})] - [I_{OUT(min)} \times (r_{DS2} + R_L)]. \end{aligned} \tag{7}$$

In contrast, the loss terms decrease the available maximum voltage, and the worst-case conditions occur at the minimum input voltage and maximum load current. Since the limiting factor, maximum duty cycle, is specified as a percentage, the switching frequency is not relevant. The maximum available output voltage is given by

$$\begin{aligned} V_{OUT(max)} = {} & D_{max} \times [V_{IN(min)} - I_{OUT(max)} \times (r_{DS1} - r_{DS2})] \\ & - [I_{OUT(max)} \times (r_{DS2} + R_L)]. \end{aligned} \tag{8}$$

Please see Reference 1 for the complete version of this article, which includes typical application examples with calculated minimum and maximum output voltages.

Conclusion

While the ideal buck converter can theoretically provide any output voltage from V_{IN} down to 0 V, practical limitations do exist. The output voltage cannot go below the internal reference voltage, and internal circuit operation may limit the minimum ON time and maximum duty cycle. Additionally, real-world circuits contain losses. These losses can act to extend the duty cycle at higher load currents and may be an advantage when output-voltage extremes exist.

Reference

1. View the complete article at
http://www-s.ti.com/sc/techlit/slyt293

For more on Linux and the consumer-electronics revolution, go to www.edn.com/article/CA6305349.

To read more about real-time embedded Linux, visit www.edn.com/article/CA450620.

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for source-code modifications but lack the bells and whistles of a commercial environment. To provide an easy-to-use IDE (integrated-development environment) like those that come with proprietary operating systems, several tool vendors and the open-source community have integrated their offerings into the graphical, open-source Eclipse platform. The IDE simplifies tool integration and execution using a plug-in architecture that allows users to easily create custom Eclipse configurations, because everything other than a small runtime kernel is a plug-in. To simplify the multitude of modifications and additions to the tool set, the Eclipse Foundation has combined product updates into an annual release package. This year's release, Ganymede, features 23 projects, including new development environments for Java and JavaScript, modeling tools, a service-oriented architecture designer, runtime projects, and a new installer to coordinate updates. You can download several Ganymede package variations along with the source code from the Eclipse Foundation Web site.

Although standard Linux is by far the most popular open-source operating system, it may not fit some embedded-system applications. Linux is a general-purpose operating system and includes a huge code base that users must tune to the hardware and requirements of their embedded devices. Most Linux distributions support a variety of architectures and protocols but require as a minimum a 32-bit processor, 2 Mbytes of RAM, and 1 Mbyte of ROM. To reduce these resource requirements, the Embedded Linux/Microcontroller Project developed the μClinux (microcontroller-Linux) derivative of the Linux kernel for microcontrollers without MMUs (memory-management units). The μClinux kernel supports a variety of microcontrollers, including many from ARM, MIPS, and Freescale, along with Analog Devices' BlackFin, Intel's i960, and Hitachi's H8 processors. You can find a complete list of supported processors, detailed tutorials, and source code at the μClinux Web site. NetBSD (Berkeley-software distribution), another open-source operating system, has gained some traction with embedded-system developers. NetBSD is a free, secure, and portable open-source version of the BSD computer operating system, a derivative of Unix. The NetBSD kernel requires a processor with an MMU and consumes resources similar to those of standard Linux. The BSD license is more liberal than that of GPL, allowing developers to retain proprietary code.

Deterministic response to real-time inputs is another important issue for embedded systems. Although the latest version includes a rewritten process-scheduler algorithm to speed task switching in multitasking applications, Linux may not be the operating system of choice for real-time projects. A better open-source, royalty-free choice for embedded applications with both limited resources and real-time requirements is the eCos (embedded configurable operating system), which RedHat software originally released. It targets devices with a memory size of a few hundred kilobytes and runs on processors from a variety of vendors, including ARM, Hitachi, Motorola, MIPS, NEC, and PowerPC. The eCos license is a slight modification of the GPL and does not require users to release application source code. It also prevents any user from making a few small improvements, calling the result a completely new system, and releasing this system under a different license.

MOBILE WARS

The hottest news in the open-source-software market is the ongoing battle over portable operating systems for platforms such as smartphones and mobile Internet devices. Late in 2007, Google and more than 30 partners announced plans for the Android mobile platform, an open-source-software stack for mobile devices that includes a Linux-based operating system, middleware, and key applications. The Open Handset Alliance will manage the source code for

the complete package and will release it when Version 1.0 is complete. Taiwan's HTC Corp is working on an Android-based handset and expects to release it in the fourth quarter of 2008. With its announcement, Google also launched the Android Developer Challenge, which will provide $10 million in awards to mobile-system applications using the Android platform. Winning applications from the already completed first phase included a range of subjects, such as communications, social networking, music, and information delivery. You can download the software-developer kit and device emulator from Google's Android-documentation Web site (**Figure 2**).

The LiMo (Linux Mobile) Foundation provides another open-source-smart-phone platform as an alternative to Android. LiMo's goal is to supply a "truly open, hardware-independent, Linux-based operating system for mobile devices." Although the foundation released Version 1.0 this year, it postponed the release of full multimedia and portability features until 2009. LiMo's focus is on creating middleware for device manufacturers and publishing the APIs (application-programming interfaces) for application developers (**Figure 3**). Several handset manufacturers, including Panasonic, Motorola, and NEC, have adopted the LiMo operating system. Lending support to the platform, the LiPS (Linux Phone Standards) Forum and mobile-carrier Verizon recently joined forces with LiMo. Although the LiMo Foundation touts the operating system as an open-source platform, you must be a paid member of the foundation to access the code base.

In other recent news that may rattle both the Android and LiMo camps, several large cell-phone manufacturers, including Nokia, Sony Ericsson, and Motorola, announced that they will combine their fragmented Symbian operating systems into one open-source platform. Although to date the operating system is not in wide use in the United States, there are thousands of Symbian-application developers worldwide. With AT&T, Samsung Electronics, Texas Instruments, and STMicroelectronics among its members, the Symbian Foundation promises to be a formidable competitor in the emerging open-source-mobile-system battleground.

As embedded devices continue to grow in complexity, the software-development task has become the largest element of a typical project budget. Graphical interfaces, network protocols, and data security are just a few of the new requirements that design teams can find as additions to their custom application software. A mounting number of designers are turning to royalty-free, open-source platforms with these and other features built-in. In fact, millions of lines of free-to-download software are available on the Internet to support every type of embedded-system-development project. As soon as the bulk of designers get past the collective learning curve and shape in-house expertise, open-source software could become the foundation of the embedded-system industry.**EDN**

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WHITE SPACES: READY FOR DEVELOPMENT PERMITS OR OFF-LIMITS?

BY BRIAN DIPERT • SENIOR TECHNICAL EDITOR

The "tragedy of the commons" and the "invisible hand of the marketplace" are two economic concepts that regularly find use in explaining the trajectories of various technologies' initial developments and evolutions (**references 1** and **2**). The influence of these concepts is evident in a diversity of issues involving broadcast-frequency spectrum in the United States and elsewhere.

Take, for example, the United States' 12 ISM (industrial/scientific/medical) bands, with 900 MHz (902 to 928 MHz), 2.4 GHz (2.4 to 2.5 GHz), and 5 GHz (5.725 to 5.875 GHz) the most common variants. The FCC's (Federal Communications Commission's) decision to open up the bands for use by low-power transmitters and receivers in a license-free manner has resulted in an unparalleled explosion of adoption, both in the consumer-electronics realm and elsewhere. However, as more consumers who fill their homes with cordless phones, garage-door openers, Wi-Fi networks, microwave ovens, and Bluetooth-based gear are discovering, regulation-free environments are also ripe settings for overuse and subsequent destructive interference (see **sidebar** "Frequency shifts").

Or take the FCC's recently concluded 700-MHz (698- to 806-MHz) spectrum auction (**Figure 1**). The band formerly corresponded to UHF (ultrahigh-frequency) television channels 52 to 69. Widespread belief was that this spectrum swath was a scarce resource and particularly precious because it could easily travel long distances and through premises' walls and other barriers. This belief led to the US Treasury's collecting a mind-boggling total of $19.592 billion from winning bidders. This fiscal success occurred despite the fact that Block D (10 MHz of cumulative bandwidth between 758 to 763 MHz and 788 to 793 MHz) failed to receive a sufficiently high minimum bid to meet the reserve price and therefore went unsold.

IS WIRELESS SPECTRUM SCARCE OR ABUNDANT? TWO COALITIONS' FRESH PERSPECTIVES ON A LONG-STANDING ISSUE HAVE PRODUCED PROMISING EARLY RESULTS, BUT OLD-GUARD OPPONENTS ARE RAISING IMPLEMENTATION ROADBLOCKS.

But is spectrum really scarce? The answer to that question depends on how you use the spectrum, say both the White Spaces Coalition and sibling organization the Wireless Innovation Alliance. (*White space* refers to the unused television channels in a region, along with the spectrum-guardband buffer between channels.) The two groups, encompassing a veritable who's who of computing and consumer-electronics hardware, software, and services companies, point out that, in any region of the United States, television broadcasters are using only a small percentage of the aggregate VHF (very-high-frequency) plus postauction remaining UHF spectrum at any time. Richard Whitt, Google's general counsel, recently remarked, "The vast majority of viable spectrum in this country simply goes unused or else is grossly underutilized. Unlike other natural resources, there is no benefit to allowing this spectrum to lie fallow. The airwaves can provide huge economic and social gains if used more efficiently, as seen today with the relatively tiny slices utilized by mobile phones and Wi-Fi services" (**Reference 3**).

The organizations' answer to this substantial inefficiency is analogous to the FAA's (Federal Aviation Administration's) approach to US airspace, which is a similarly finite resource. As aircraft enter a

region's airspace, the FAA assigns them routes, altitudes, and surrounding buffer zones that enable them to evade other aircraft within that region. And, when an aircraft departs a region, its airspace allocation returns to an available-resource pool for subsequent use by others.

The White Spaces proposal for PAN (personal-area-network), LAN (local-area-network), and WAN (wide-area-network) applications is reminiscent of FAA traffic management. It differs in one key area, however: The FAA relies on regional air-traffic control to manage airspace-resource allocation. With White Spaces, no centralized spectrum-governing body exists. Instead, White Spaces technology-based equipment manages itself, dynamically sensing what portions of the spectrum other transmitters are using at any time and, in response, dynamically reconfiguring itself to evade potential interference scenarios.

The concept is intriguing, but is it achievable in real-life-usage environments? White Spaces backers insist that it is; they point to, for example, similar avoidance techniques in place with 802.11a (through the 802.11h extension) and 802.11n to avoid conflict with 5-GHz-based medical equipment and military- and weather-radar systems. They also offer a number of additional implementation options that will, if necessary, even better avoid conflict, albeit at added cost. Incumbent users of VHF and UHF spectra, notably television broadcasters and developers and users of wireless microphones and medical equipment, are less sanguine about their potential new next-door neighbors. To the extent that they buy into the White Spaces concept at all, they demand spectrum licensing and other restrictions that White Spaces promoters retort will so restrict price and flexibility as to render the approach dead on arrival—arguably the ultimate aspiration of detractors.

AT A GLANCE

- The White Spaces Coalition aspires, by intelligently and efficiently using spectra, to shift the supply-versus-demand curve in a low-cost direction without cultivating ISM (industrial/scientific/medical)-band-reminiscent overexploitation.
- A map of the VHF (very-high-frequency) and UHF (ultrahigh-frequency) bands may appear to offer plenty of holes for cognitive radios to harness, but the spectrum is actually crowded, albeit, in many cases, by unlicensed, and thereby illegally operating, equipment.
- Initial FCC (Federal Communications Commission) testing of White Spaces proof-of-concept prototypes has produced less-than-perfect results that adversaries have extrapolated to a blanket indictment of the technology.
- Licensing available VHF and UHF subbands on a region-by-region basis could result in more complete use of available spectra but doesn't play to the low cost, portability, and other advantages that White Spaces promoters tout.
- White Spaces backers have recently floated additional implementation concessions to placate opponents. It's unclear what additional costs their inclusion will incur or whether White Spaces technology even needs superset-spectrum-avoidance capabilities.

INCONSISTENT HISTORY

If you became aware of the White Spaces controversy only through the last few months of heavy media attention, you might be surprised to learn that industry and regulatory debate over the topic is more than a half-decade old (see **sidebar** "Implementation plans?"). In May 2003, the FCC sponsored an industry workshop on so-called cognitive radio, "a radio that can change its transmitter parameters based on interaction with the environment in which it operates" (**Reference 4**). Later that year, the FCC published an NPRM (notice of proposed rule-making) on the subject, following it in May 2004 with another notice specific to television-broadcast bands. In that same period, the IEEE began working on its White Spaces-based 802.22 WRAN (wireless-regional-area-network) standard.

The US Senate in February 2006 introduced a bill that proposed opening unused television channels to alternative uses in a license-free manner. A subsequent October 2006 FCC decision opened the White Spaces for use by high-power, fixed-location, professionally installed, and, therefore, expensive transmitters. Such equipment would, for example, provide a competitive broadband-access scheme to incumbent approaches, such as cable, DSL (digital-subscriber line), fiber, and satellite—one with particular appeal in poorly served rural areas.

That FCC ruling also tentatively opened the White Spaces to use by lower-power, portable, consumer-activated

FREQUENCY SHIFTS

At press time in June, the FCC (Federal Communications Commission) was supposedly wrapping up its second wave of White Spaces equipment testing, targeting report publication in October. If all goes well, first equipment availability will coincide with the Feb 17, 2009, NTSC (National Television System Committee) sunset.

I have serious doubts about this schedule and suspect a clearer perspective on where the FCC stands will be available by the time you read this article. As such, monitor the Brian's Brain blog (www.edn.com/briansbrain) for timely updates on the topic, along with supplemental materials. Look for "White Spaces" in the posts' subject lines.

I'll also share through the blog key points from an interview I conducted with Avnera's chief executive officer, Manpreet Khaira. Avnera's wireless-audio-chip sets operate in the 2.4-GHz ISM (industrial/scientific/medical) band, not in the White Spaces-candidate VHF (very-high-frequency) and UHF (ultrahigh-frequency) areas, but they face challenges from similar crowded-spectrum-interference issues. Khaira explains how the company's products sense and account for the presence of other 2.4-GHz-band transmitters, along with other design trade-offs, such as frequency of sensing, degree of receiver-to-transmitter back-channel communication, antenna design, and 2.4-GHz-band-only versus 2.4- and 5-GHz-band cognizance.

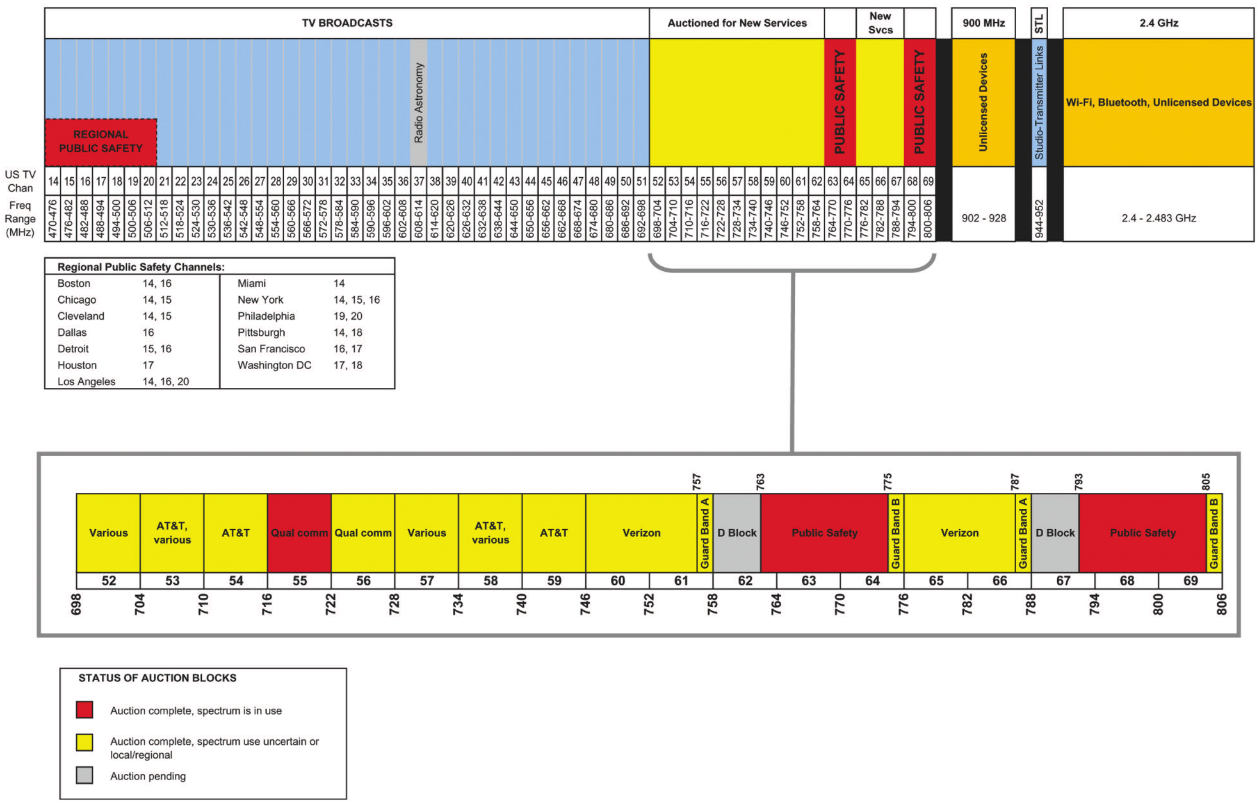

Figure 1 A post-NTSC-sunset spectrum map of UHF and higher-frequency bands showcases White Spaces opportunities along with potential problem areas (courtesy Shure).

equipment, albeit with several key qualifiers. Additional FCC testing and subsequent feature specificity would ensure that such equipment could operate in an interference-free manner, and equipment targeting consumers would be unavailable for purchase until after the Feb 17, 2009, NTSC (National Television System Committee) phase-out date.

The reasons for the delayed first-sale date derive from both technical and logistics causes. At the time, advance preparations for the early-2008 700-MHz-spectrum auction were under way. The FCC was also assisting early-adopter broadcasters with their ATSC (Advanced Television Systems Committee) equipment and service launches. These activities consumed FCC resources. The complete transition to ATSC in early 2009 will also result in a spectrum environment that's friendlier to White Spaces. Redundant NTSC broadcasts will no longer exist, rendering more channels available for alternative uses. Also, the steeper frequency cutoffs defining the edges of each ATSC channel's footprint, in contrast with NTSC predecessors and courtesy of more modern and precise broadcast equipment, result in additional usable between-channel spectrum (**Figure 2**).

FCC testing of White Spaces prototype equipment has so far produced mixed results. The first round of analysis encompassed transmission-capable gear from Microsoft (Prototype A) along with a receiver-only unit from Philips (Prototype B) (**Figure 3**). A July 2007 report deemed the Microsoft hardware unacceptable in performance, revealing, "where a DTV (digital-television) signal was strong enough to be received on the TV, the scanner reported its channel to be free or available 40 to 75% of the time" (**Reference 5**).

The Philips receiver fared better; it was "generally able to reliably detect DTV signals at −115 dBm in the single-channel tests and at −114 dBm in the two-channel tests." And the White Spaces Coalition's subsequent analysis of Prototype A prompted a letter to the FCC indicating that the device had a broken spectrum-scanning subsystem and that a backup device that the FCC failed to also evaluate "detected DTV signals at a threshold of −114 dBm in laboratory bench testing with 100% ac-

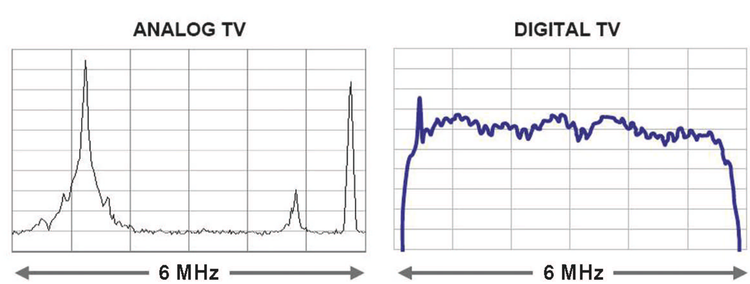

Figure 2 The frequency footprint of an ATSC broadcast channel exhibits steeper cutoff ramps on either side than its NTSC predecessor, thereby leaving more available White Spaces spectrum in the buffer guardband between channels (courtesy Shure).

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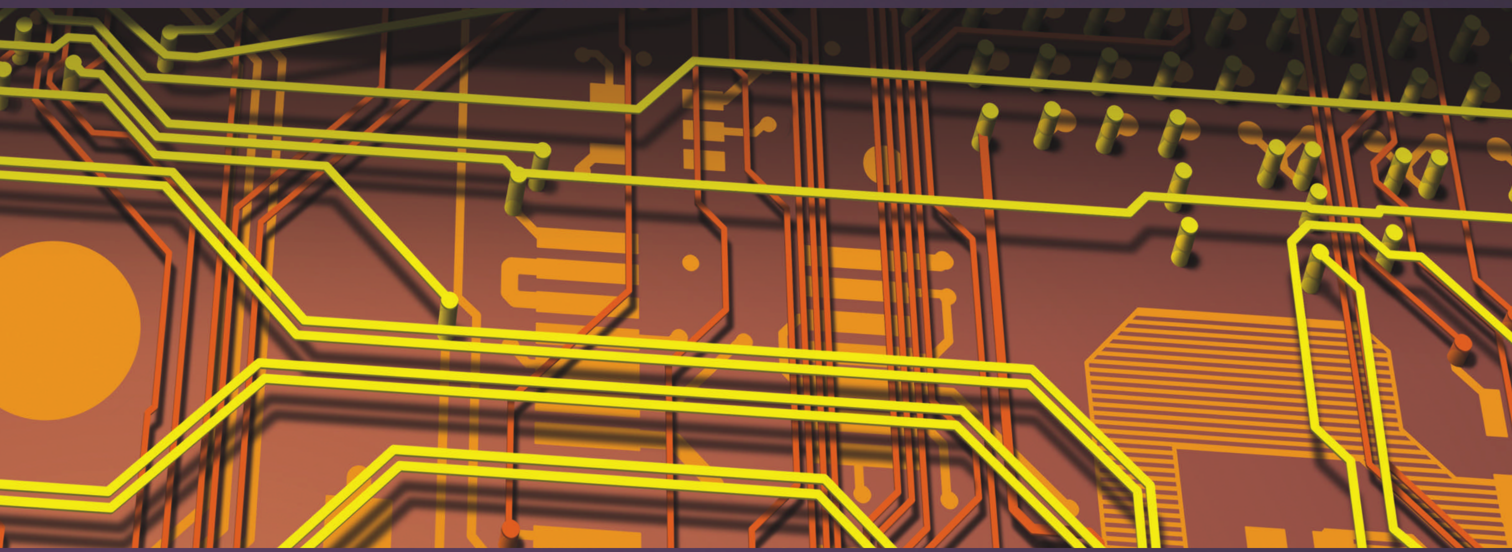

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curacy, performing exactly as expected" (**Reference 6**). But related FCC testing of digital-cable-television receivers near White Spaces equipment also produced troubling interference (**Reference 7**).

The second round of testing began in late January 2008 and consisted of laboratory measurements followed by in-field evaluations. Equipment submissions again came from Microsoft (in partnership with Metric Systems), Philips, Adaptrum, and Motorola. Once again, the unlucky bug bit Microsoft ... twice. An initially functional unit in mid-February began exhibiting power-supply-related issues after more than a week of operation; it would work only when initially booted or after a lengthy intermediary cool-down cycle (**Reference 8**). Another prototype failed in late March. If White Spaces advocates were hoping to sway the FCC to their side of this controversial issue, they weren't helping their cause by repeatedly shooting themselves in the foot.

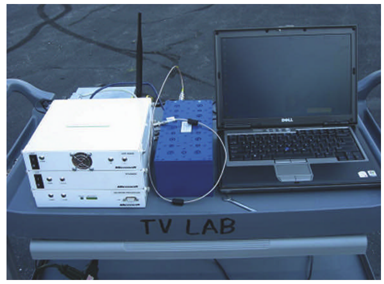

Figure 3 Prototype A was the first of several Microsoft-supplied White Spaces proof-of-concept units to fail during FCC testing.

SELF-SERVING REASONING

White Spaces detractors seized on the equipment failures as a sweeping indictment of the technology's trustworthiness not to interfere directly with broadcast signals or indirectly through first-adjacent-channel proximity. Accompanying late-2007 advertisements in Washington, DC-area newspapers was a television spot featuring a senior citizen, a television showing an interference-plagued Washington Redskins football game, and a voice-over that ominously intoned, "Digital television means you can watch your favorite shows with a crystal-clear picture. But if some high-tech companies like Microsoft get their way, your picture could freeze and become unwatchable. They want unlicensed electronics devices to operate on channels used for digital TV. Say goodbye to your perfect digital picture!" (**Reference 9**).

After the failure of the second Micro-

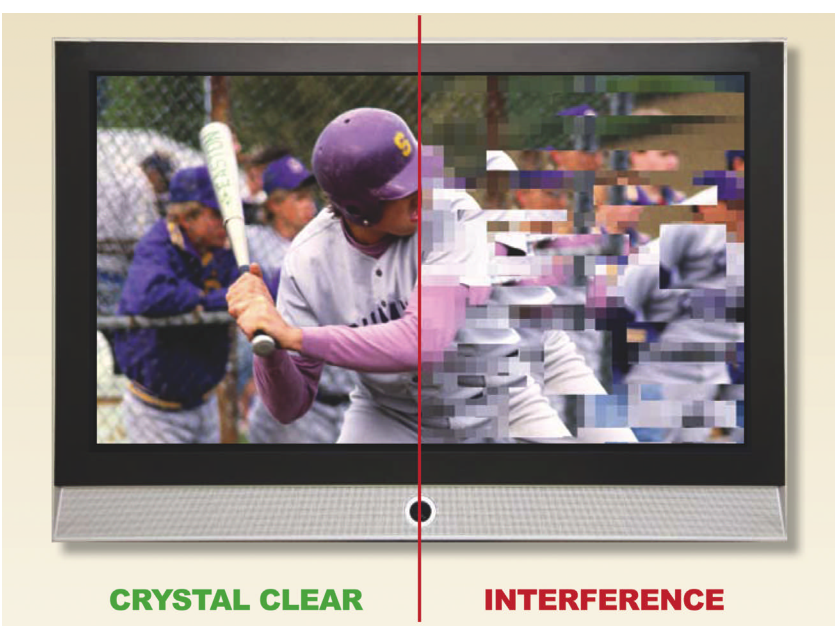

Figure 4 The NAB's (National Association of Broadcaster's) FUD (fear/uncertainty/doubt) campaign directly targets technology-ignorant consumers with pessimistic simplifications and ignores the fact that those consumers, not the NAB, own the spectrum from which it's fighting to bar White Spaces devices.

IMPLEMENTATION PLANS?

For some of you, this write-up may be your first significant exposure to the White Spaces controversy. Others of you, I suspect, are well-aware of the issues associated with this topic and are closely following developments at the FCC (Federal Communications Commission) and elsewhere. I welcome your posted comments at the version of this article on *EDN's* Web site (www.edn.com/080807cs). I'd also like to hear from readers in other countries, whose regulatory bodies may have a different perspective on White Spaces-spectrum equivalents and who may be further along in their implementation processes than their peers in the United States.

soft proof-of-concept prototype in mid-February, NAB (National Association of Broadcasters) Vice President Dennis Wharton proclaimed, "By failing two out of two tests at the FCC, Microsoft and the Wireless Innovation Alliance have demonstrated that unlicensed devices are not ready for prime time. This admission by 'white-space' proponents vindicates beyond doubt the interference concerns expressed by broadcasters, sports leagues, wireless-microphone companies, and theater operators" (**Reference 10**). In weighing the validity of the NAB's complaints and overall strategy, keep in mind that the spectrum that broadcasters are currently using doesn't actually belong to them; they lease it on a no-cost basis from the US government (**Figure 4**).

As noted, some camps, including Sprint Nextel, T-Mobile, and the overarching CTIA (Cellular Telecommunications and Internet Association), favor fee-based licensing of available VHF and UHF spectrum in a region as an alternative White Spaces approach. Pragmatically, these players likely see White Spaces-based mobile data, including VOIP (voice-over-Internet Protocol) services, as potential threats to their current and planned future wireless-data programs, such as 3GPP (third-generation-partnership project) LTE (long-term evolution) and WiMax (worldwide interoperability for microwave access). They therefore have a vested interest in increasing the cost, limiting location flexibility, and as much as possible slowing implementation of White Spaces development. Pragmatically, too, as the recently concluded 700-MHz-spectrum auction demonstrates, licensed White Spaces spectra would likely also end up in the possession of a few large telecom operators instead of, as White Spaces advocates wish, cultivating a Wi-Fi-reminiscent ecosystem of equipment, software, and services.

Radio-astronomy- and medical-telemetry-industry participants aren't strong White Spaces backers, either; the FCC in 1963 reserved UHF Channel 37 for radio astronomy and in 1974 formally banned television-broadcaster use. White Spaces promoters have signaled their willingness to avoid using channels 36 to 38 to avoid potential destructive interference with such equipment. Shure publicly leads the other large, vocal anti-White Spaces alliance, the Microphone Interests Coalition. The members' complaints border on hypocrisy; although the law requires owners and operators of FCC Part 74 devices, such as wireless microphones, to obtain licenses, few do. "We-were-here-first" arguments lose much of their punch when, as it turns out, "we were here first, illegally" more accurately describes the situation.

But with respect to wireless microphones, White Spaces advocates are also guilty of oversimplification. They point to the prevalence of unlicensed VHF and UHF microphones, all generally working in a problem-free manner, as a proof of concept of the spectrum approach that White Spaces technology is attempting to also adopt. This pitch is at first glance persuasive, but further inspection reveals several notable holes.

+ See the "White Spaces" posts at www.edn.com/briansbrain for supplemental information on this article's topics.

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First, wireless microphones aren't spectrum-diverse; they transmit and receive on a fixed frequency. Therefore, unless you use them in multiple widespread regions with different spectrum-occupancy characteristics, they'll either always work or never work. And, as Shure's manager of educational and technical communications, Chris Lyons, pointed out during his April NAB-conference presentation, wireless-microphone transmitters' output is several orders of magnitude weaker than local-television-broadcast signals (**Reference 11**). A VHF- or UHF-based municipal-broadband-service network, conversely, would have broadcast-power characteristics closer to those of a local-television affiliate.

ADDITIONAL CONCESSIONS

In attempting to appease the technology's detractors, White Spaces Coalition and Wireless Innovation Alliance members acting on their own and together have in recent months offered a number of additional implementation proposals, most notably in a Google presentation to the FCC in late March—ironically, one week after the conclusion of the 700-MHz-spectrum auction. Although these ideas would increase the cost and diminish the bandwidth robustness of White Spaces devices, the alternative scenario of no White Spaces devices is less palatable. Conversely, though, if spectrum-detection and -avoidance techniques by themselves prove to be sufficiently robust, White Spaces-technology implementers will likely discard the additional steps that follow in favor of minimizing the equipment's bill-of-materials costs.

As noted, Channel 37 conflicts with radio-astronomy and hospital-telemetry gear. However, avoidance of this channel plus a one-channel buffer on either side isn't a panacea; official FCC assignment of WMTS (wireless-medical-telemetry service) in the 608- to 614-MHz band to medical instrumentation didn't happen until 1998, and some hospitals are likely still using older equipment that employs other broadcast frequencies. Also up for potential channel-avoidance consideration are UHF channels 14 to 20, which find use for regional public-safety broadcasts.

Supplementing the broadcast-audio signals from wireless-microphone transmitters, beacons broadcasting on as-yet-undetermined frequencies would more definitively direct White Spaces equipment to avoid using relevant portions of VHF and UHF spectra. Cost estimates for beacons vary widely, from tens to hundreds of dollars. White Spaces promoters' quotes lie predictably at the low end of the range; detractors' forecasts, at the high end. Detractors also argue that they shouldn't need to pay anything to ensure White Spaces technology's coexistence with their products.

White Spaces devices might even incorporate GPS (global-positioning-system) receivers, enabling them to discern their exact location at any time, along with dynamic access to a database of nearby VHF and UHF transmitters. Using this data, they could avoid the frequencies that those transmitters are using. And, when they lack access to the database, they don't transmit until they again assess that they can safely do so.

Google's interest in the White Spaces concept is understandable, given that the company's continued fiscal success hinges on users' convenient and low-cost or free access to its services, and that Google isn't yet an ISP (Internet-service provider) and therefore relies on ISP partners as intermediaries. White Spaces technology, coupled with the company's past success in getting the FCC to add open-access requirements to 700-MHz-spectrum licenses, which Google initially bid on but lost to Verizon, conceptually would make Google less vulnerable to the whims of such service-provider middlemen. However, whereas a GPS receiver might exist in an Android-operating-system-based mobile phone, for example, adding it to a device that doesn't otherwise need geolocation capabilities might prove too costly. EDN

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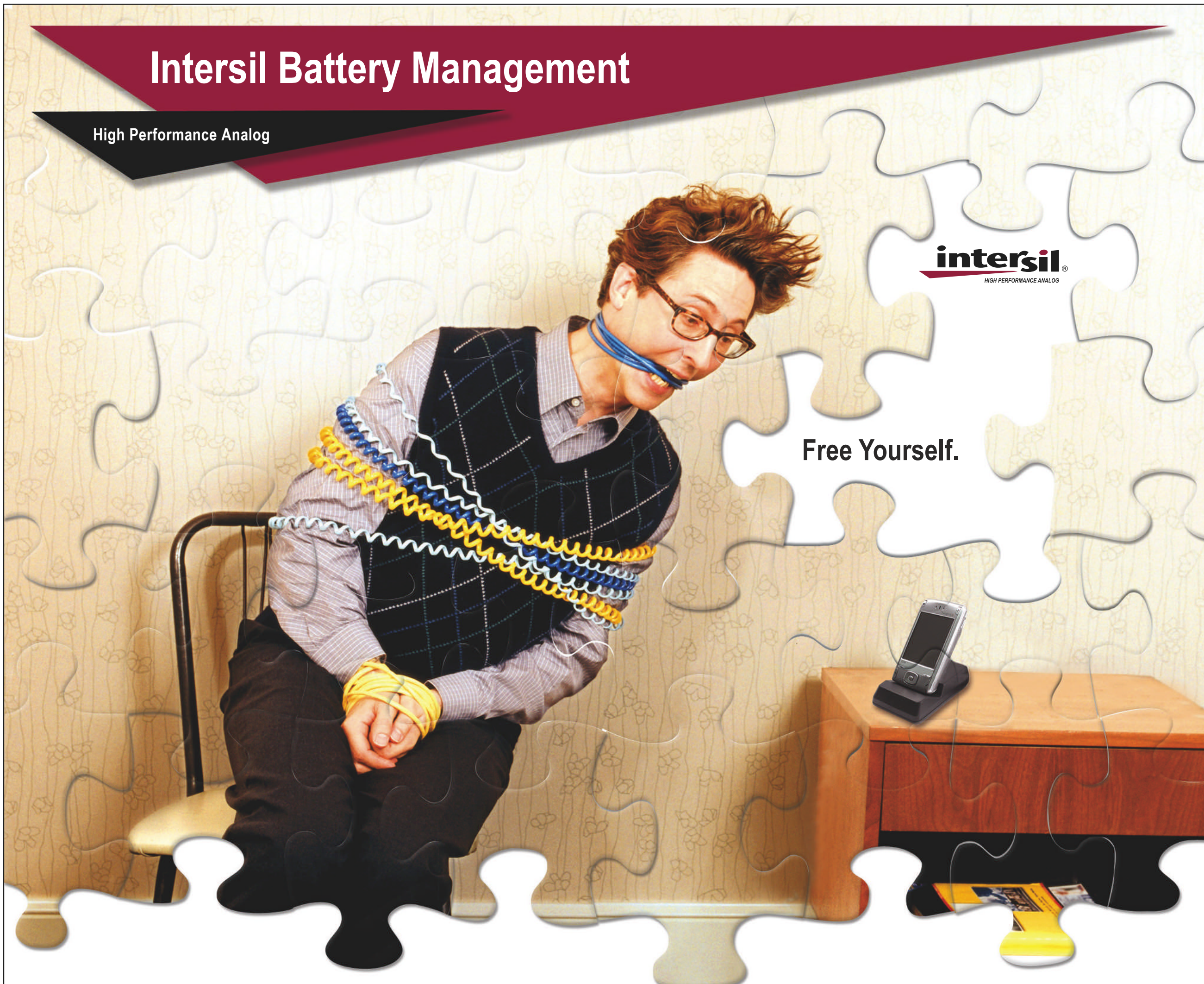

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TECHNOLOGY edge℠

Defining PowerWise® Performance-to-Power Product Metrics

White Paper

Richard F. Zarr, Chief Technologist

Introduction

As with all things that are held to standards, a measurement must be established to compare similar items. For example, a standard for measuring acceleration of an automobile is the 0 to 60 miles per hour (MPH) or 0 to 100 kilometers per hour (KPH) in units of seconds. This measurement notes the number of seconds to accelerate from a complete stop to 60 MPH (100 KPH). Using this metric, a buyer could then evaluate the value of several aspects of a vehicle such as horsepower-to-weight ratio, traction control, effects of all-wheel drive, and other features in a single unit of measure.

As the need for more energy-efficient equipment increases, similar methods will be required to determine the best power-to-performance ratio of a component or system. National Semiconductor has developed product efficiency metrics as a means for measuring a device's power consumption to its level of performance. The top tier of products within these metrics are classified as members of the PowerWise® product family. *Table 1* shows the various component families and the associated metrics and performance thresholds used to select the highest performance-to-power ratio products.

Switching Regulator Metrics

Power conversion is the simplest performance metric to understand. There is only the power out (P_{OUT}) divided by the power in (P_{IN}) which yields percent efficiency. Most modern integrated switchers have efficiencies greater than 80%; how-ever, to be best-in-class, efficiencies need to reach 85% to 95% or better. Integrated circuit (IC) designers accomplish this through various internal architectures and the ability to lower the quiescent current when loads are light through switching modes or by entering sleep mode. To be considered a PowerWise brand switching regulator, National has set the bar by category, based on topology or application.

Switching Regulator Metrics – High V_{IN} to V_{OUT} Ratio

In a buck topology where the input voltage is much higher than the output voltage ($V_{IN} / V_{OUT} \geq 7$), the duty cycle of the system is very small. This limitation presents designers difficulty in achieving high efficiencies at low duty cycles. Issues include accurately sensing the current limit, adequate drive and on time of the high-side switch and minimizing, the dead time (time used to prevent shoot through current) between the high- and low-side switch.

In a boost topology, where the output is much higher than the input ($V_{OUT} / V_{IN} \geq 7$), large currents are present in the switch to achieve the desired output voltage (and load current). To be efficient in moving this current, FETs with very low on resistance are required. This is usually accomplished by making the FETs larger or by process selection. Additionally, challenges in achieving high efficiency for boost regulator designs are similar to those of buck regulators and require similar considerations.

In both of these applications, if a device used in a correctly engineered power supply is capable of reaching efficiencies above 85%, it is considered an excellent example and a member of the PowerWise product family. The regulator IC is only one part of a complex system of components, so correctly matching the additional passive components (such as the inductor and output capacitor) is critical. National provides tools such as its online WEBENCH® design environment to assist engineers in making these calculations.

Switching Regulator Metrics – Switching Frequencies above 2 MHz

There are system tradeoffs when selecting the switching frequency of a switched power converter. In converter designs with a given ripple current, as switching frequency increases, the chosen inductance value should decrease as shown in the equation below. However, hysteretic losses

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Table 1

Efficiency Ratings for PowerWise Products

Product Family	Metric	Threshold	Units
Power Management			
Switching Regulators/Controllers ($V_{IN}/V_{OUT} \geq 7$)	Peak Efficiency	≥ 85	%
Switching Regulators/Controllers ($F_{SW} \geq 2$ MHz, $V_{IN}/V_{OUT} \geq 1.5$)		≥ 90	
Switching Regulators/Controllers (all others, $V_{IN}/V_{OUT} \geq 1.5$)		≥ 95	
Switching Controllers for Isolated Power Supplies		≥ 90	
Low-Noise Linear Regulators	$\frac{e_n}{P_{out}}$	≤ 10	μV_{RMS}/mW
LED Lighting*			
LED Drivers (boost)	Peak Efficiency	≥ 85	%
LED Drivers (buck)		≥ 90	
LED Drivers (buck-boost)		≥ 80	
Data Conversion			
Giga-Sample ADCs	$\frac{P}{2^{ENOB} \cdot F_s \cdot ch}$	≤ 9	pJ/conversion
High-Speed ADCs		≤ 2.5	
Low-Power ADCs (INL ≤ ±2 LSB)		≤ 3.5	
Amplifiers and Comparators			
Op Amps	$\frac{I_{cc}}{GBW \cdot ch}$	≤ 120	µA/MHz
Micropower Amplifiers ($I_{CC} < 11$ µA)		≤ 100	
Low-Noise Amplifiers ($e_n < 4$ nV/√Hz)		≤ 145	
Precision Amplifiers ($V_{OS} < 0.2$ mV)		≤ 127	
Current Feedback		≤ 7	
Decompensated Amplifiers		≤ 3.3	
Comparators	$\frac{I_{cc} \cdot t_{resp}}{ch}$	≤ 20	µA•µS
Interface			
Equalizers	$\frac{P}{T_r \cdot ch}$	≤ 20	pJ/bit
Buffers		≤ 40	
Timing/Clocking Solutions			
Clock Jitter Cleaners, Generators, Distributors, and PLL+VCO	$\frac{P \cdot t_j}{ch}$	≤ 120	mW•pS
Audio			
Class-D Amplifiers	Efficiency	≥ 85	%
Low Noise Audio Amplifiers ($V_{CC} \geq 30$V, GBW ≥ 40 MHz)	$\frac{P}{dbLIN \cdot ch}$	≤ 0.88	mW/dbLIN
Low Noise Audio Amplifiers ($V_{CC} \leq 5$V, GBW ≥ 4 MHz)		≤ 0.04	
Far-Field Noise Suppression Microphone Amplifiers	$\frac{P}{dbSUP \cdot ch}$	≤ 0.17	mW/dbSUP

ch = number of channels
dbLIN = Amplifier Linearity
dbSUP = Noise Suppression
e_n = output noise
ENOB = Effective Number of Bits
F_s = sampling frequency (usually the max sampling rate of the device)
GBW = Gain Bandwidth Product

I_{cc} = supply current
INL_{range} = range of the Integral Non-Linearity
P = power
T_r = transfer rate
t_j = jitter performance
t_{resp} = response time

Note: *LED drivers must meet the efficiency ratings and have an additional power-saving feature to qualify as a PowerWise product.

$$\Delta I_L = \frac{1}{f \cdot L} V_{OUT} \left(1 - \frac{V_{OUT}}{V_{IN}} \right)$$

in the inductor and gate drive currents increase with frequency, directly affecting the efficiency of the power conversion. Managing these tradeoffs well can yield power converters with efficiencies above 90%, which is the metric for this group of switching regulators to be members of the PowerWise family of products.

Low-Noise Low Dropout Regulator Metrics

The use of a low-dropout regulator (LDO) may not seem to be an energy-efficient design; however, there are times when LDOs are the best fit for a system. This occurs in applications where low noise is critical to the operation of the system. This class of LDO regulators is specifically designed for sensitive analog load applications such as RF transceivers, precision amplifiers, and data converters where the output noise is a key parameter for operation. Since power is required to reduce noise, a slightly different metric is used. This includes the output noise (e_n) which is expressed in microvolts Root Mean Square (RMS) divided by the maximum output power. The better the noise figure for a given output power, the better the performance of the device.

LED Drivers

There are various ways to improve the efficiency of lighting systems. One simple way is to move away from incandescent bulbs to LEDs (Light Emitting Diodes). Modern LEDs exceed the lumens/watt of incandescent lighting providing efficient replacement in many applications such as traffic lights, automotive lighting, signage, and other general illumination. Since LED light is proportional to the current through them and they have a nonlinear voltage to current relationship, maintaining constant current is essential to maintain a given light output and color purity.

LEDs may be used in various applications and therefore require different topologies in switching converters to provide the necessary current. As shown in ***Table 1***, when using an LED in a flash mode, such as in a digital camera, high current pulses are common requiring an efficiency of 90% or greater. These devices also require flash duration control to be a member of the PowerWise product family. In applications where there are a large string of LEDs, a boost topology is required which places additional requirements on the switching converter. In this mode, an efficiency of 85% or better provides excellent performance.

Additionally, some applications require both boosting when a voltage source is low or running in buck (step-down) mode when the input voltage is high. This is common in battery operated devices. This also puts additional requirements on the converter and lowers the overall efficiency. In this LED topology, an efficiency of 80% or better is considered very good and difficult to achieve. Similar to buck switching regulators, LED drivers that always run in buck mode (high input voltage to current out) may see higher efficiencies and values of 90% or higher as best-in-class performance. Along with efficiency, LED drivers must also have power-saving features such as sophisticated dimming control, automatic ambient light adjustment to qualify as PowerWise products.

Data Converter Metrics

The industry figure of merit for data conversion devices and systems is based on the amount of energy consumed per conversion cycle. This metric targets systems that rely on the AC performance of the converter, thus the dependency on Effective Number of Bits (ENOB). This metric is expressed in pico-joules per conversion (pJ/conversion). It can be calculated by either the ENOB or the Signal-to-Noise and Distortion (SINAD) of the converter.

$$\frac{P \cdot 10^{12}}{2^{ENOB} \cdot f_s \cdot ch} = \frac{P \cdot 10^{12}}{2^{\left(\frac{SINAD - 1.76}{6.02}\right)} \cdot f_s \cdot ch}$$

The equations above utilize the International System (SI) of units for power and frequency and result in picojoules (pJ) per conversion. Above, *P* is power consumed by the device

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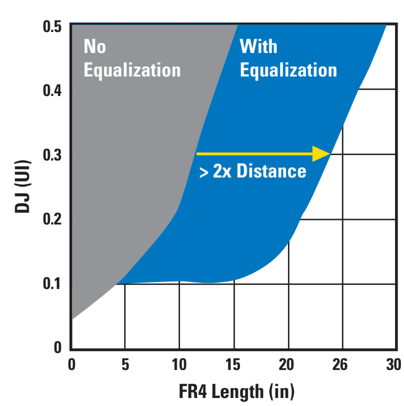

DS80EP100 12.5 Gbps Power-Saver Equalizer performance graph

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or system in watts, ENOB is the effective number of bits for the converter or conversion system and f_s is the max sampling frequency (Hz). The value ch is the number of channels in the converter to normalize all values to a single channel. The SINAD also may be used to calculate this term (as shown in the second equation) since:

$$ENOB = \frac{SINAD - 1.76}{6.02}$$

Amplifier Metrics

Processing analog signals requires amplifiers to scale or filter, detect, add gain or otherwise modify the signal in a predictable way without distortion. There are many classes of amplifiers, including general purpose, low noise, precision, and high-speed current feedback. The overall performance metric for any amplifier is based on the ability to pass signals without distortion. This metric is tied to the bandwidth so the common performance metric used by National is the gain bandwidth product along with the power it takes to run a single channel of the amplifier.

Since there are so many special variations of operational amplifiers, additional metrics must be used beyond the performance-to-power ratio. In ***Table 1***, performance amplifiers have additional metrics (such as input voltage noise) next to the amplifier type which will be the threshold for any amplifier in that category.

Amplifiers will continue to improve in performance providing higher speeds or bandwidth at lower power. As applications move away from large supply rails, the overall power consumption will decrease providing the ability to improve the performance-to-power ratios. Amplifier IC design is trending toward single supply amplifiers with extremely large gain bandwidth products at very low power. These amplifiers will accomplish this through lower parasitic losses and improved internal architectures.

Comparator Metrics

Similar to amplifiers, comparators are judged on the speed at which the output changes state for a given supply current. The faster a comparator switches for a given current, the better its rating. For comparators to be considered part of the PowerWise product family, the output must switch from one state to the other with no more than 20 µS*µA. This can also be thought of as 20 µA for every µS it takes to switch as a maximum. If a comparator switches in 5 µS and uses only 2 µA of current, the rating would be 10 uS*µA, making it a PowerWise family device.

Equalizer and Data Buffer Metrics

The ability to move data over media efficiently at high speed is the metric for interface devices such as LVDS, Mobile Pixel Link (MPL), Current Mode Logic (CML) and others. Typically, more power is required to drive copper cable faster due to cable loss and non-linear effects. Improved drivers combined with the proper receivers and equalizers yield a higher value metric due to a higher data transfer rate, lower power or both.

The metric is defined as: $\frac{P}{T_r \cdot ch}$

Where P is power dissipation of the driver and T_r is the data transfer rate. To be a member of the PowerWise product family, a value of 20 pJ/bit (picojoules per bit transferred over the media) or better is required for equalizers and a value of 40 pJ/bit or better is required for data buffers. As CML technology progresses and further enhancements are made to equalizers which remove the dependency on pre-emphasis and de-emphasis, even higher performance will be achieved. There is still a great deal of life left in copper wires.

Timing Solution Metrics

As systems increase in performance and run at higher and higher speeds, accurate clocks are required to maintain proper synchronization and communication. Even data acquisition systems that use high performance ADCs require low jitter clocks – any jitter directly affects the performance of the system. The equation below defines the effects of jitter on the Signal-to-Noise Ratio (SNR) of a data acquisition system:

$$SNR_{jitter} = 20\,LOG\left(\frac{1}{2\pi f_{max} t_j}\right)$$

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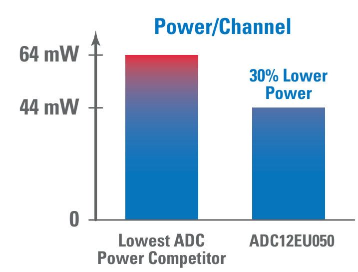

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The metric chosen by National for clock conditioners includes the consumed power as well as the jitter performance as seen in ***Table 1***. A value of 55 ps*mW per channel or better is required for a clock conditioner to be considered a member of the PowerWise product family. The lower the power or jitter of a clock conditioner, the higher the power/performance rating. These values are normalized to a single channel.

Audio Solution Metrics

There are several different classes of audio devices targeted toward lowering system power. These not only include low noise and class-D power amplifiers, but also include new technology such as analog-based far-field noise suppression. Class-D amplifiers are qualified as PowerWise products by their conversion efficiency. A power amplifier with greater than 85% conversion efficiency will qualify as a PowerWise family device.

For low-noise audio amplifiers, there are two classes – high voltage and low voltage. Both are qualified on their power consumption versus linearity – a very important parameter for audio.

The metric is defined as follows:

$$\frac{P}{LIN \cdot ch}$$

Above *P* is the power consumed and *LIN* is the linearity of the amplifier (*ch* is the number of channels as before). The high-voltage devices (Vcc ≥ 30V) should be less than 0.88 mW/LINdb and the low- voltage devices (Vcc ≤ 5V) should be less than 0.04 mW/LINdb.

Far-field noise suppression is a technology that uses multiple microphones to cancel out ambient noise, providing a higher signal-to-noise ratio in applications such as mobile phones.

Here the metric is: $$\frac{P}{NS \cdot ch}$$

Again, *P* is power consumed and *NS* is the level of noise suppression. Digital solutions can use as much as 10 to 20 times the power required by analog solutions for the same level of noise suppression. The Far-Field Noise Suppression (FFNS) PowerWise devices should have less than 0.17 mW/NS_{db} (DSP based solutions are around 2.25 mW/NS_{db}).

Conclusion

National has a rich technological history of designing energy-efficient ICs for applications where heat dissipation, size constraints, and system reliability are key design priorities. For the growing number of designs where energy-efficiency is a high consideration, National has developed the PowerWise line of products to make it easy for design engineers to select the products that use the least amount of power for the application. As requirements become more demanding, metrics for PowerWise products will become stricter. As more engineers move to higher energy-efficiency requirements, these metrics and products will provide guidance and solutions to these tough design challenges.

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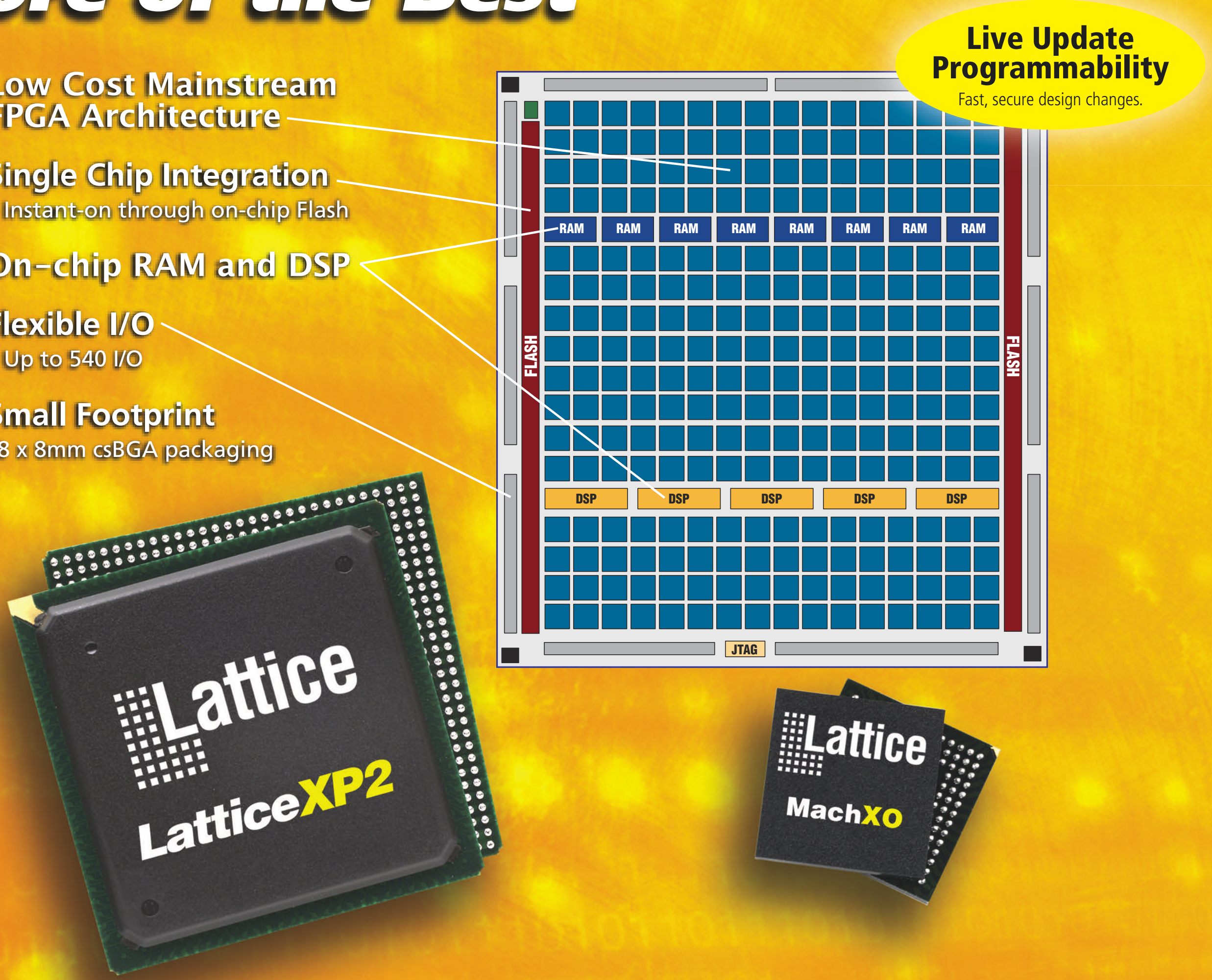

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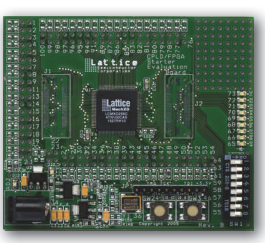

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High-voltage, low-noise dc/dc converters

YOU CAN MAKE A 1-kV DC/DC CONVERTER WITH ONLY 100 µV OF NOISE.

Photomultipliers, avalanche photodiodes, ultrasonic transducers, condenser microphones, radiation detectors, and similar devices require high-voltage, low-current biasing. Additionally, the high voltage must be free of noise. A common requirement is less than 1 mV of noise, and these devices sometimes require noise to be less than a few hundred microvolts. Switching-regulator configurations cannot normally achieve this performance level without employing special techniques. One aid to achieving low noise is the fact that load currents rarely exceed 5 mA. This freedom permits the use of output-filtering methods that are otherwise impractical.

This article describes a variety of circuits featuring outputs of 200 to 1000V with less than 100 µV of output noise in a 100-MHz bandwidth. Special techniques, most notably power stages that minimize high-frequency harmonic content, enable this performance. Although sophisticated, all these examples use standard, commercially available magnetic components. This provision should help you quickly arrive at a manufacturable design.

Before proceeding any further, understand that you should use caution in the construction, testing, and use of the circuits this article describes. High-voltage, lethal potentials are present in these circuits. Use extreme caution in working with and making connections to these circuits. Again, these circuits contain dangerous, high-voltage potentials.

RESONANT ROYER-BASED CONVERTERS

The resonant Royer topology suits low-noise operation due to its sinusoidal power delivery (**references 1** and **2**). The resonant Royer is attractive because transformers for LCD-backlight service are readily available. These transformers are available from multiple sources, well-proven, and competitively priced. **Figure 1**'s resonant Royer topology achieves 100-µV-p-p noise at 250V output by minimizing high-frequency harmonics in the power-drive stage. The self-oscillating resonant Royer circuitry comprises Q_2, Q_3, C_1, T_1, and L_1. Current flow through L_1 causes the T_1, Q_2, Q_3, and C_1 circuitry to oscillate in resonant fashion, supplying sine-wave drive to T_1's primary with resultant sinelike high voltage appearing across the secondary.

T_1's rectified and filtered output feeds back to amplifier-reference A_1, which biases the Q_1 current sink, completing a control loop around the Royer converter. L_1 ensures that Q_1 maintains constant current at high frequency. Milliampere-level output current allows the presence of a 10-kΩ resistor in the output filter. This resistor greatly aids filter performance with minimal power loss. The low cur-

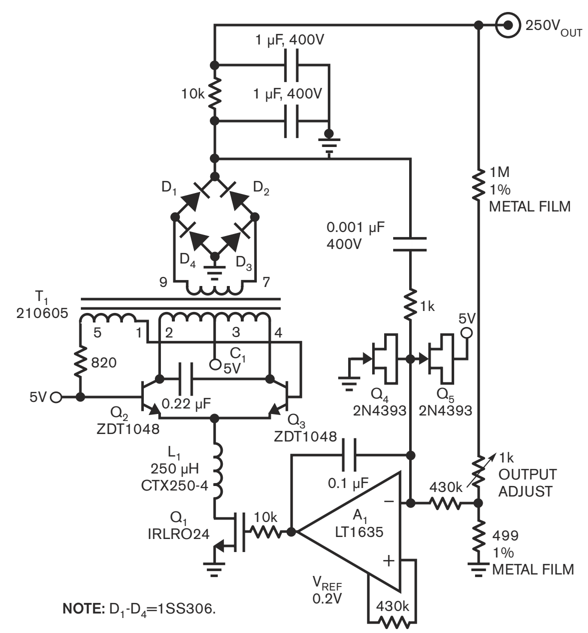


Figure 1 This current-fed resonant Royer converter produces a high-voltage output. Amplifier A_1 biases the Q_1 current sink. This step creates a feedback loop that stabilizes the output voltage. Amplifier A_1's 0.001-µF-capacitor, 1-kΩ-resistor network creates a phase lead relative to the output filter, thereby optimizing transient response. Low-leakage clamp diodes D_5 and D_6 protect A_1.

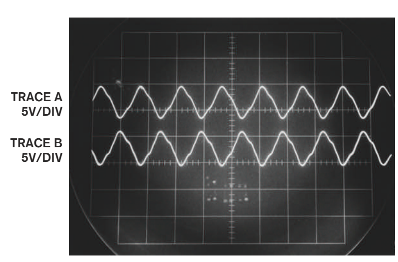


Figure 2 The waveforms of a resonant Royer collector are distorted sinusoids, containing no high-frequency content.

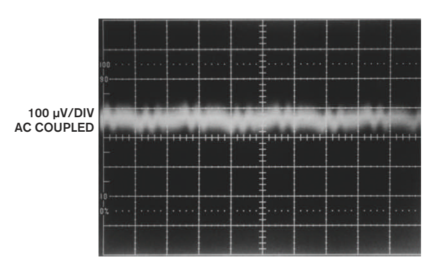


Figure 3 The output noise of the circuit in Figure 1 is barely discernible relative to the instrumentation's 100-µV noise floor.

rent requirements permit certain freedoms in the output filter and feedback network (see **sidebar** "Feedback considerations in high-voltage dc/dc converters" at www.edn.com/ms4295). The RC path to A_1's negative input combines with the 0.1-μF capacitor to compensate A_1's loop. D_5 and D_6, low-leakage clamps, protect A_1 during start-up and transient events. Although **Figure 2**'s collector waveforms are distorted, no high-frequency content is present.

The circuit's low harmonic content combines with the RC-output filter to produce a transcendently clean output. Output noise (**Figure 3**) is just discernible in the monitoring instrumentation's 100-μV noise floor (**Reference 3**).

Figure 4's variant of **Figure 1** maintains 100-μV output noise and extends the input-supply range to 32V. Q_1 may require heat-sinking at high input-supply voltage. Converter and loop operation remains the same as in **Figure 1**, although **Figure 4** re-establishes compensation components to accommodate the LT1431 control element.

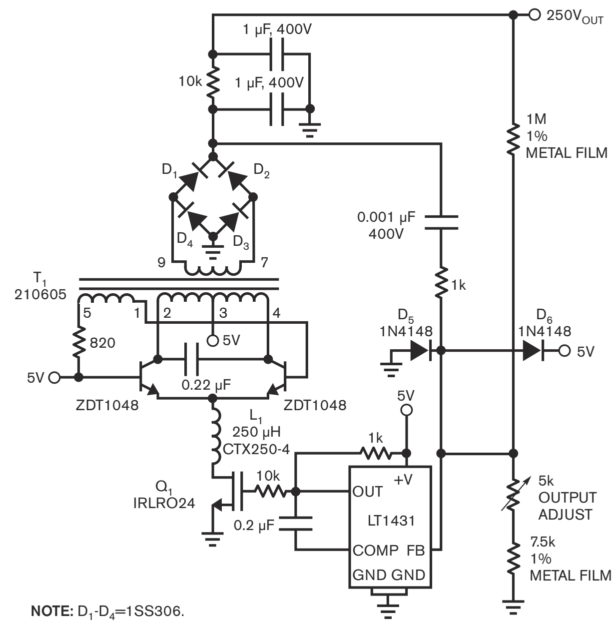
The previous resonant Royer examples use linear control of converter current to furnish harmonic-free drive. The trade-off is decreased efficiency, particularly as input voltage scales. You can improve efficiency by employing switched-mode current drive to the Royer converter. Unfortunately, such switched drive usually introduces noise. However, you can counter this undesirable consequence.

Figure 5 replaces the linearly operated current sink with a switching regulator. The Royer converter and its loop are the same as in **Figure 4**; **Figure 6**'s transistor-collector waveshape (Trace A) is similar to that of the other circuits. The high-speed, switched-mode current-sink drive (Trace B) efficiently feeds L_1. This switched operation improves efficiency but degrades output noise. **Figure 7** shows switching-regulator harmonic clearly responsible for 3-mV-p-p output noise—about 30 times greater than that of the linearly operated circuits.

Careful examination of **Figure 7** reveals almost no Royer-based residue. Switching-regulator artifacts dominate the noise. Eliminating this switching-regulator-originated noise and maintaining efficiency requires special circuitry, but this circuitry is readily available (**Figure 8**). The resonant Royer converter and its loop are reminiscent of the circuits in the preceding **figures**. The fundamental difference is the LT1534 switching regulator that uses controlled transition times to retard high-frequency harmonic and maintain efficiency. This approach blends switching and linear-current-sink benefits (**Reference 3**). R_V and R_I set the voltage and current-transition rate, respectively, which represents a compromise between efficiency and noise reduction.

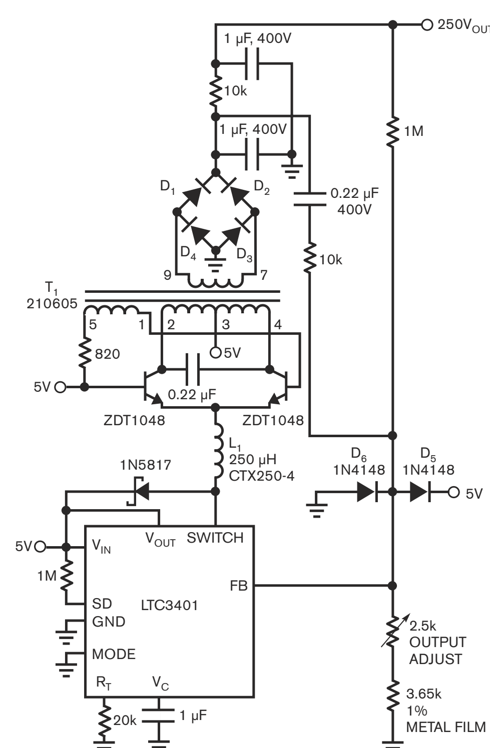
Figure 9's Royer collector waveshape (Trace A) is nearly identical to the one that **Figure 5**'s circuit produces. Trace B, depicting LT1534-controlled transition times, markedly departs from its **Figure 5** counterpart. These controlled transition times dramatically reduce output noise (**Figure 10**) to 150 μV p-p—a 20-fold improvement over **Figure 7**'s LTC3401-based results.

Figure 11 is essentially identical to **Figure 8**, except that it produces a −1000V output. A_1 provides low impedance, inverting feedback to the LT1534. **Figure 12a**'s output noise measures less than 1 mV. As before, resonant Royer ripple dominates the noise; no high-frequency content is detectable.



NOTE: D_1-D_4=1SS306.

Figure 4 This variant of Figure 1 employs the LT1431 regulator, maintains 100-μV output noise, and extends the input-supply range to 32V. Transistor Q_1 may require a heat sink if input-supply voltages are high.



NOTE: D_1-D_4=1SS306.

Figure 5 In this circuit, a switching regulator replaces the linearly operated current sink of Figure 4. This approach minimizes heating, although the output noise increases.

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It is worth noting that this noise figure proportionally improves with increased filter-capacitor values. For example, **Figure 12b** indicates only 100-μV noise with 10-times-higher filter-capacitor values, although the capacitors are physically large. The original values represent a reasonable compromise between noise performance and physical size.

PUSH-PULL CONVERTERS

Controlled transition techniques are also directly applicable to push-pull architectures. **Figure 13** uses a controlled transition push-pull regulator in a simple loop to control a 300V output converter. Symmetrical-transformer drive and controlled switching-edge times promote low output noise. The D_1- through D_4-connected damper further minimizes residual aberrations. In this case, the output filter uses inductors, although you could employ appropriate resistor values. **Figure 14** displays smooth transitions at the transformer secondary outputs. (Trace A is T_1 Pin 4, and Trace B is T_1 Pin 7.) The absence of high-frequen-

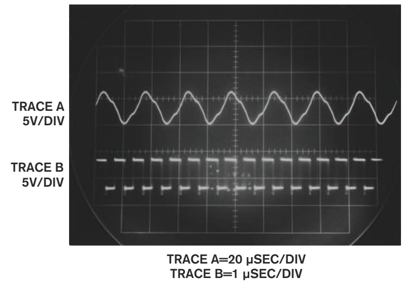

Figure 6 The resonant Royer collector waveshape (Trace A) is similar to that of the previous circuits. An efficient, high-speed, switched-mode current-sink drive feeds inductor L_1 (Trace B).

cy harmonic results in extremely low noise. **Figure 15**'s fundamental-related output residue approaches the 100-μV measurement noise floor in a 100-MHz bandpass. This performance is spectacularly low noise in any dc/dc converter, and certainly in one providing high voltage. Here, at 300V output, noise represents less than 1 part in 3 million.

Figure 16 is similar, except that output range varies from 0 to 300V. An LT3439, which contains no control elements, replaces the LT1533. It simply drives the transformer with 50%-duty-cycle, controlled switching transitions. A_1, Q_1, and Q_2 enforce feedback control by driving current into T_1's primary center tap. A_1 compares a resistively derived portion of the output with a user-supplied control voltage. These values produce a 0 to 300V output in response to a 0 to 1V control voltage. An RC network from Q_2's collector to A_1's positive input compensates the loop. Collector waveforms and output-noise signature are nearly identical to those in **Figure 13**. Output noise is 100 μV p-p over the entire 0 to 300V output range.

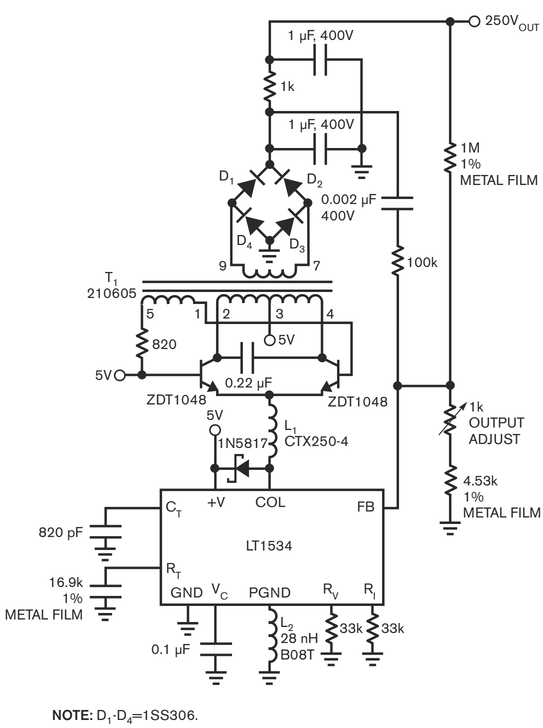

Figure 8 The LT1534 switching regulator features controlled transition times that minimize high-frequency harmonics and maintain low heat dissipation. The approach blends the benefits of switching- and linear-current-sink circuits.

FLYBACK CONVERTERS

You don't usually associate flyback converters, with their abrupt, poorly controlled energy delivery, with low-noise output. However, careful magnetic selection and layout can

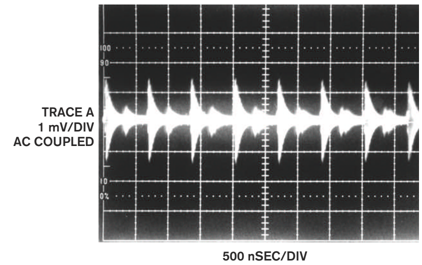

Figure 7 The switching-regulator harmonic in Figure 5 results in 3-mV-p-p output noise.

provide surprisingly good performance, particularly at low output current. **Figure 17**'s design provides 200V from a 5V input (**references 4** and **5**). The scheme is a basic inductor-flyback-boost regulator with some important deviations. Q_1, a high-voltage device, resides between the LT1172 switching regulator and the inductor. This approach permits the regulator to control Q_1's high-voltage switching without undergoing high-

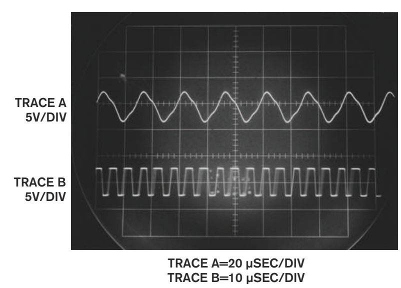

Figure 9 The resonant Royer collector waveshape is identical to that of the LT3401 circuit in Figure 5 (Trace A). The controlled transition times of the LT1534 current sink attenuate the high-frequency harmonics (Trace B).

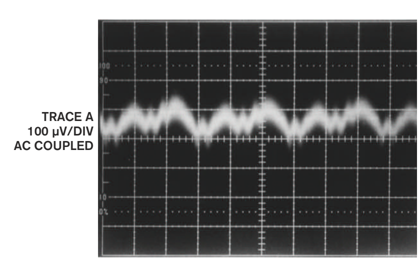

Figure 10 The controlled transition times dramatically lower noise to 150 μV p-p, a 20-fold improvement over that of Figure 7.

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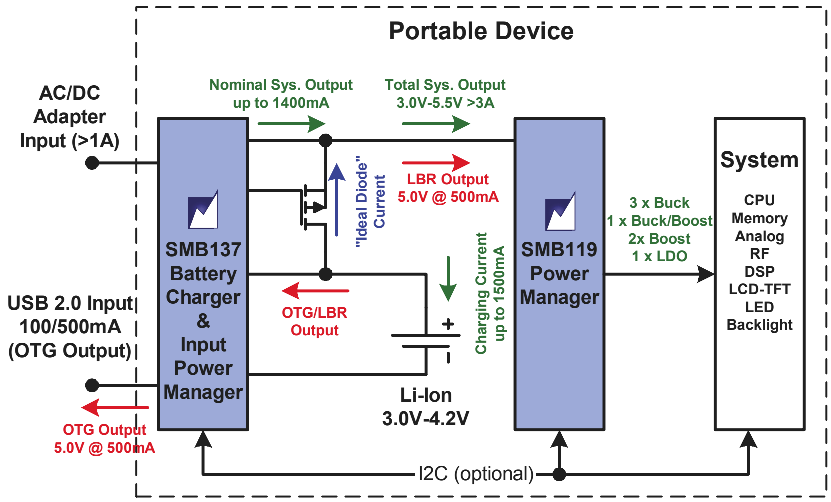

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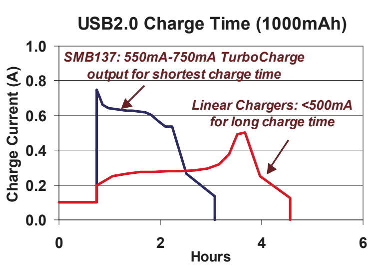

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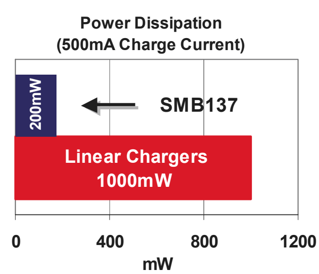

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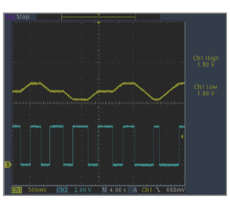

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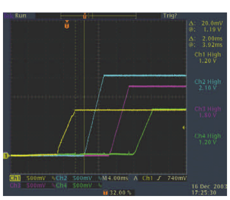

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# of Inputs/Outputs	2/2	1/1	1/1	1/1
Maximum Charge Current (mA)	1500	1250	900	210/525
TurboCharge™ Output	Automatic	Automatic	Software/uC	
CurrentPath™ Control	X			
USB On-The-Go Power	X	X		
Low-Battery Recovery Mode	X			
I2C Interface	X	X	X	X
Programmable Algorithm	X	X	X	X
UV/OV/Thermal/Timer Safety	X	X	X	X
Package	3.6x3.3 CSP-30	3.1x2.1 CSP-20	2.1x1.3 CSP-15	2.1x1.3 CSP-8
Total Solution Size (mm2)	50	28	31	7.5

* () Indicates maximum input overvoltage "holdoff"

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Step-down (Buck)	3 or 4	3 or 4	3 or 4	4
Step-up (Boost)	2 or 4	2 or 3	1 or 2	
Inverter (Buck-Boost)	0 or 1			
Battery Charger	1		1	
LDO	1	1	1	
Package Size (mm)	9x9	7x7	7x7	5x5

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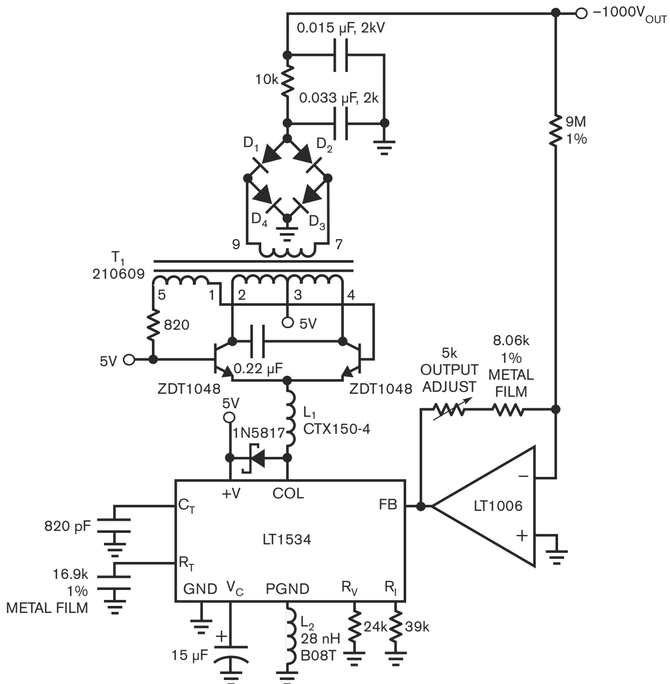
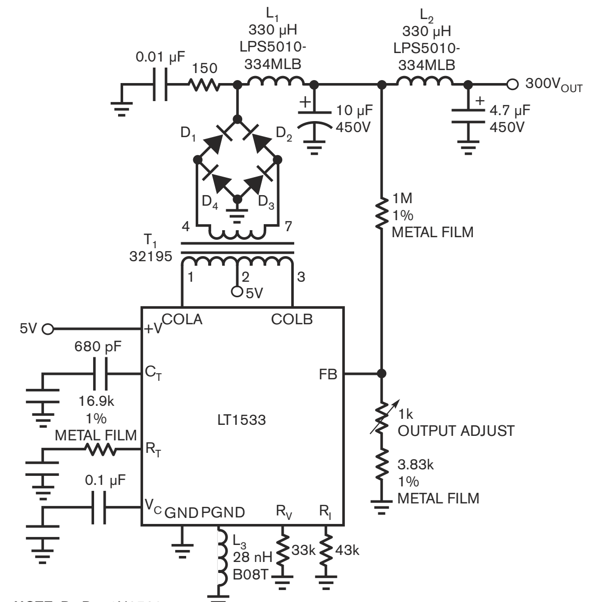


NOTE: D_1-D_4=1N6529.

Figure 11 This −1000V negative-output converter uses the controlled-transition-time feature of the LT1534. Amplifier A_1 provides low impedance, inverting feedback to the LT1534 IC.



NOTE: D_1-D_4=1N6529.

Figure 13 This converter circuit features a push-pull drive with controlled transitions and provides a 300V output. The symmetrical-transformer drive and slow edge transitions promote low output noise.

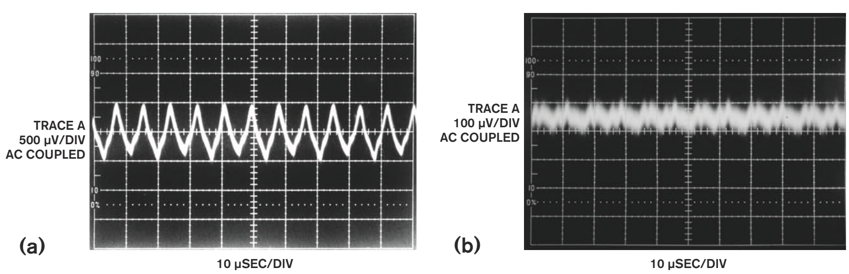


Figure 12 The −1000V converter's output noise measures less than 1 mV—that is, 1 ppm, or 0.0001%—in a 100-MHz bandwidth (a). The resonant Royer ripple voltage dominates the residue. There is no detectable high-frequency content. Output noise decreases to 100 µV by using 10-times-larger filter capacitors than those in Figure 11 (b). The penalty is the size of the capacitors.

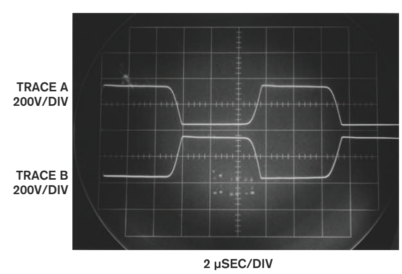


Figure 14 The outputs of the transformer secondary have no high-frequency artifacts.

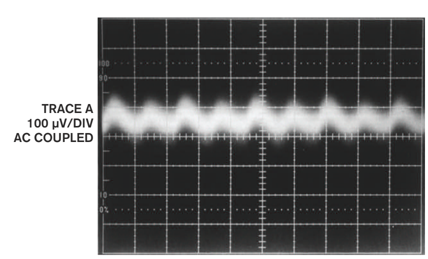


Figure 15 The output noise of the push-pull converter circuit in Figure 13 is barely discernible relative to the instrumentation's 100-µV noise floor. No wideband components appear in the 100-MHz measurement passband.

voltage stress. Q_1, operating as a cascode with the LT1172's internal switch, withstands L_1's high-voltage flyback events (**references 6** through **10**).

Diodes associated with Q_1's source-terminal clamp, L_1, originated spikes arriving through Q_1's junction capacitance. The high voltage is rectified and filtered, forming the circuits' output. The ferrite bead and 100 and 300Ω resistors aid filter efficiency (**references 11** and **12**). Feedback to the regulator stabilizes the loop and the V_C-pin network provides frequency compensation. A 100-kΩ path from L_1 bootstraps Q_1's gate drive to about 10V, ensuring saturation. The output-connected diode provides short-circuit protection by shutting down the LT1172 if the output is accidentally grounded.

Figure 18's traces A and C are LT1172 switch current and voltage, respectively. Q_1's drain is Trace B. Current-ramp termination results in a high-voltage flyback event at Q_1's drain. A safely attenuated version of the flyback appears

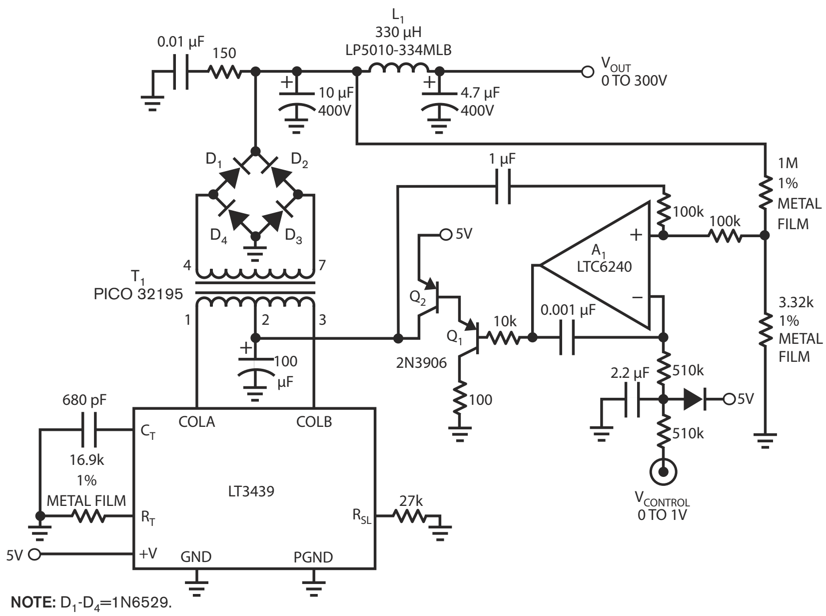


Figure 16 This circuit provides full-range adjustability. The control input, $V_{CONTROL}$, sets transformer T_1's drive voltage through Q_1 and Q_2. A 1-MΩ/3.32-kΩ resistive divider provides feedback that A_1's input capacitors stabilize. Waveforms are similar to those of Figure 13. The output noise is 100 µV p-p.

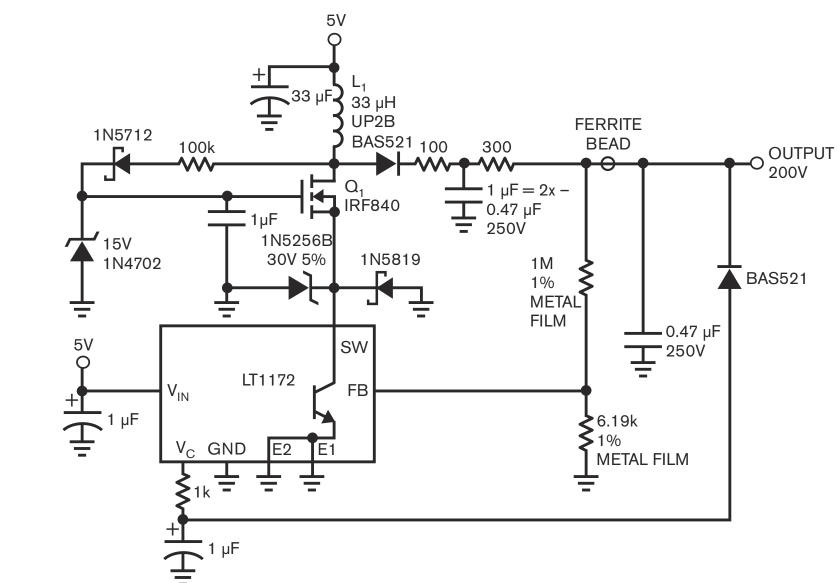


Figure 17 This converter has an output of 5 to 200V. Transistor Q_1 is in cascode with the LT1172 and switches the high voltage. This approach allows a low-voltage regulator to control the output. Diode clamps protect the regulator from transients. Flyback events at L_1 bootstrap Q_1's gate drive through the 100-kΩ resistor. The diode that connects to the output and the 300Ω resistor provide short-circuit protection. The ferrite bead and the 100 and 300Ω resistors minimize high-frequency output noise.

at the LT1172 switch. The sinusoidal signature, due to inductor ring-off between conduction cycles, is harmless. **Figure 19**, output noise, comprises low-frequency ripple and wideband, flyback-related spikes measuring 1 mV p-p in a 100-MHz bandpass.

In a transformer-coupled flyback cir-

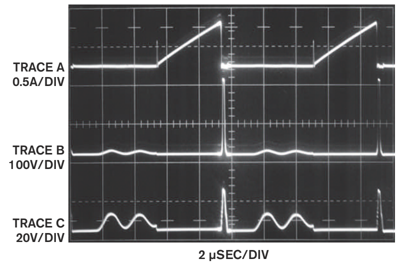


Figure 18 Waveforms for the 5 to 200V converter include the LT1172 switch current and voltage (traces A and C, respectively) and Q_1's drain voltage (Trace B). The termination of the current ramp results in a high-voltage flyback event at the drain of Q_1. A safely attenuated version appears at the LT1172 switch. The inductor ring-off between current-conduction cycles creates the sinusoidal signature, but it is harmless.

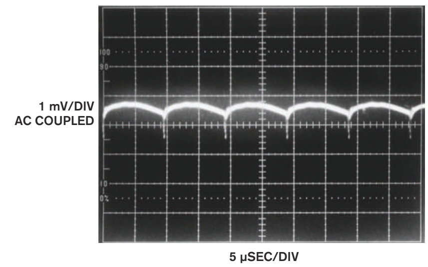


Figure 19 The output noise of the circuit in Figure 17 is 1 mV p-p in a 100-MHz bandpass. The noise comprises low-frequency ripple and wideband, flyback-related spikes.

cuit, the transformer secondary provides voltage step-up referred to the flyback-driven primary (**Figure 20**). The 4.22-MΩ resistor supplies feedback to the regulator, closing a control loop. A 10-kΩ, 0.68-μF filter network attenuates high-frequency harmonic with minimal voltage drop. **Figure 21** clearly shows flyback-related transients in the output noise, although they are within 300 μV p-p.

The circuit in **Figure 22** employs the LT3468 photoflash-capacitor charger as a general-purpose, high-voltage dc/dc converter. Normally, the LT3468 regulates its output at 300V by sensing T_1's flyback-pulse characteristic. This circuit allows the LT3468 to regulate at lower voltages by truncating its charge cycle before the output reaches 300V. A_1 compares a divided-down portion of the output with the program input voltage. When the output-derived potential at A_1's negative input exceeds the program voltage at A_1's positive input, A_1's output goes low, shutting down the LT3468. The feedback capacitor provides ac hysteresis, sharpening A_1's output to prevent chattering at the trip point. The LT3468 remains shut down until the

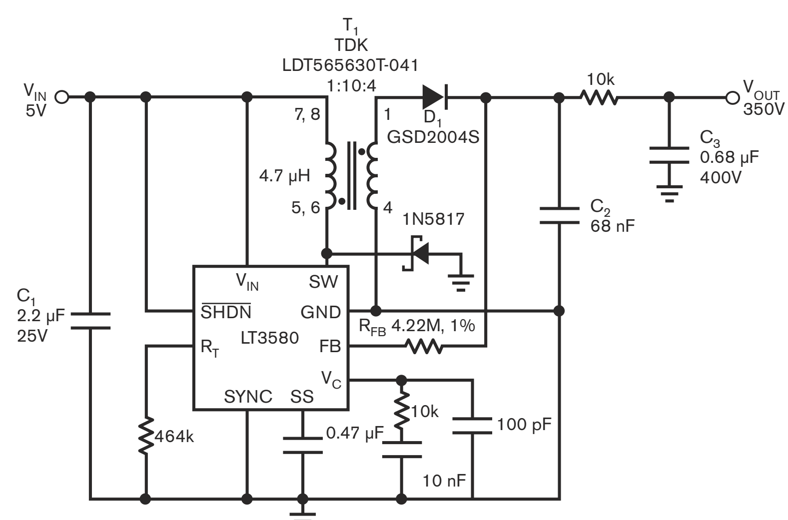


Figure 20 This 5V-powered transformer-coupled flyback converter produces a 350V output (courtesy Albert M Wu, Linear Technology).

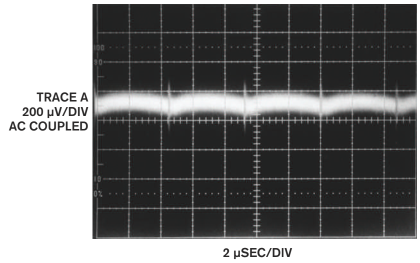


Figure 21 The high-speed transients in the circuit of Figure 20 produce a noise signature within 300 µV p-p.

output voltage drops low enough to trip A_1's output high, turning it back on. In this way, A_1's duty cycle modulates the LT3468, causing the output voltage to stabilize at a point that the program input determines.

Figure 23's 250V-dc output (Trace B) decays down about 2V until A_1 (Trace A) goes high, enabling the LT3468 and restoring the loop. This simple circuit works well, regulating over a programmable 0 to 300V range, although its inherent hysteretic operation mandates the unacceptable 2V output-ripple noted. The loop-repetition rate varies with the input voltage, output setpoint, and load, but the ripple is always present.

The circuit in **Figure 24** greatly reduces ripple amplitude, although complexity increases. The circuit's postregulator reduces the output ripple and noise of **Figure 22**'s circuit to only 2 mV. A_1 and the LT3468 are identical to **Figure 23**'s circuit, except for the 15V zener diode in series with the 10-MΩ/100-kΩ feedback divider. This component causes C_1's voltage, and hence Q_1's collector, to regulate 15V above the $V_{PROGRAM}$ input-dictated point. The $V_{PROGRAM}$ input also routes to the A_2-Q_2-Q_1 linear postregulator. A_2's 10-MΩ/100-kΩ feedback divider has no zener diode, so the postregulator follows the $V_{PROGRAM}$ input with no offset. This arrangement forces 15V across Q_1 at all output voltages. This figure is high enough to eliminate undesirable ripple and noise from the output and keep Q_1's dissipation low.

Q_3 and Q_4 form a current limit, protecting Q_1 from overload. Excessive current through the 50Ω shunt turns on Q_3. Q_3 drives Q_4, shutting down the LT3468. Simultaneously, a portion of Q_3's collector current turns on Q_2 hard, shutting off Q_1. This loop dominates the normal regulation feedback, protecting the circuit until you remove the overload.

Figure 25 shows just how effective the postregulator is. When A_1 (Trace A) goes high, Q_1's collector (Trace B) ramps up in response. Note the LT3468's switching artifacts on the ramp's upward slope. When the A_1-LT3468 loop is satisfied, A_1 goes low and Q_1's collector ramps down. The output postregulator (Trace C), however, rejects the ripple, showing only 2 mV of noise. The slight blurring of the trace derives from A_1-LT3468 loop jitter.

CIRCUIT CHARACTERISTICS

Table 1 (at www.edn.com/ms4295) summarizes and notes the salient characteristics of the circuits in this article. This **table** is only a generalized guideline and not an indicator of capabilities or limits. Too many variables and exceptions exist to accommodate the cate-

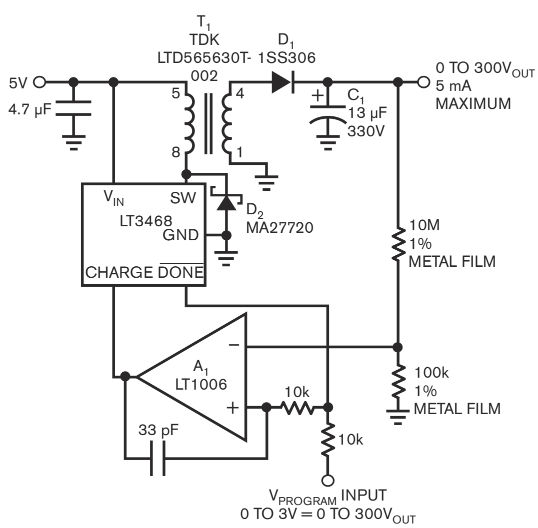


Figure 22 This regulator output is voltage-programmable between 0 and 300V. Amplifier A_1 controls the regulator output by modulating the duty cycle of the LT3468/T_1 dc/dc converter's power delivery.

gorical statement the **table** implies. The interdependence of circuit parameters makes summarizing or rating various approaches a hazardous exercise. There is simply no intellectually responsible way to streamline the selection and design process if you want optimum results. A meaningful choice must be the outcome of laboratory-based experimentation. Too many interdependent variables and surprises exist for a systematic, theoretically based selection. Tables such as this one seek authority through glib simplification, and simplification is disaster's deputy. Nonetheless, **Table 1** (at www.edn.com/ms4295), in all its glory, lists input-supply range, output voltage, and current, along with comments for each circuit. **EDN**

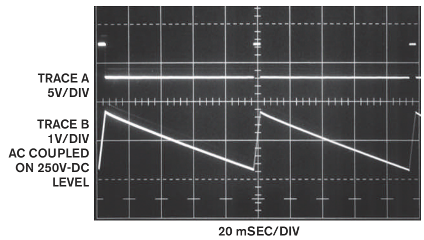


Figure 23 The duty-cycle-modulated operation of the circuit in Figure 22 shows that the high-voltage output (Trace B) ramps down until A_1 (Trace A) goes high. This approach enables the LT3468/T_1 to restore the output. The loop-repetition rate varies with input voltage, output setpoint, and load.

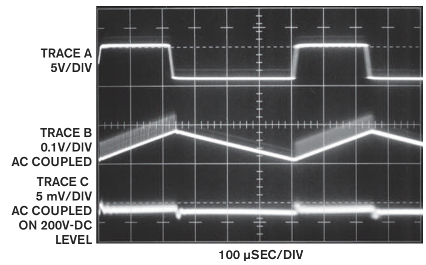


Figure 25 The low-ripple output (Trace C) is apparent in the postregulator's operation. Traces A and B are the output of A_1 and Q_1's collector, respectively. The blurring of the trace, right of the photo's center, derives from loop jitter.

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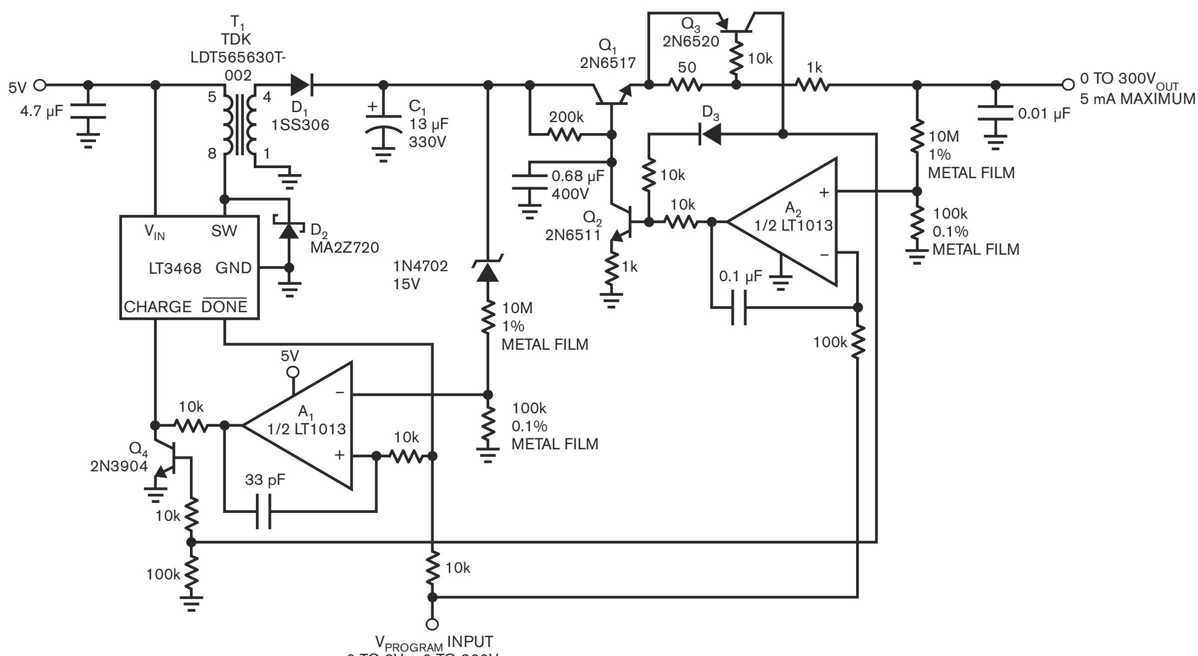

Figure 24 Adding postregulation to the circuit of Figure 22 reduces the output ripple from 2V to 2mV. An LT3468-based dc/dc converter, similar to the one in Figure 22, delivers high voltage to the collector of Q_1. Amplifier A_2 and Q_1 and Q_2 form a tracking, high-voltage linear regulator. The zener diode sets Q_1's collector-to-emitter voltage to 15V, ensuring tracking with minimal power dissipation. Transistors Q_3 and Q_4 limit the short-circuit output current.

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AUTHOR'S BIOGRAPHY

Jim Williams is a staff scientist at Linear Technology Corp (www.linear.com), where he specializes in analog-circuit and instrumentation design. He has served in similar capacities at National Semiconductor, Arthur D Little, and the Instrumentation Laboratory at the Massachusetts Institute of Technology (Cambridge, MA). A former student at Wayne State University (Detroit), Williams enjoys sports cars, art, collecting antique scientific instruments, sculpture, and restoring old Tektronix oscilloscopes.

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LT3474/-1	Buck	400:1 PWM	4 to 36	9/25	1.00	TSSOP-16E
LT3475/-1	Dual Buck	3000:1 PWM	4 to 36 (40 Max.)	9/25	1.50 x 2	TSSOP-20E
LT3476	Quad Buck, Boost, Buck/Boost Mode	1000:1 PWM	2.8 to 16	36	1.00 x 4	5mm x 7mm QFN-38
LT3477	Buck, Boost, Buck/Boost Mode	DC/PWM	2.5 to 25	40	2.00	4mm x 4mm QFN-20, TSSOP-20E
LT3478/-1	Buck, Boost, Buck/Boost Mode	3000:1 PWM	2.8 to 36 (40 Max.)	40	4.00	TSSOP-16E
LT3486	Dual Boost	1000:1 PWM	2.7 to 24	35	0.10 x 2	3mm x 5mm DFN-16
LT3496	Triple Buck, Boost, Buck/Boost Mode	3000:1 PWM	3 to 30 (40 Max.)	45	0.50 x 3	4mm x 5mm QFN-28
LT3517/18	Buck, Boost, Buck/Boost Mode	5000:1 PWM	3 to 30 (40 Max.)	45	1.0/2.0	4mm x 4mm QFN-16
LT3590	Buck Mode	200:1 PWM	4.5 to 55	n/a	0.05	2mm x 2mm DFN-6, SC-70
LT3595	Buck Mode	3000:1 PWM	4.5 to 45	n/a	0.05 x 16	5mm x 9mm QFN-56
LT3755/56	Buck, Boost, Buck/Boost Mode	3000:1 PWM	4.5 to 40/6 to 100	60/100	Ext. FET	3mm x 3mm QFN-16, MSOP-16E
LTC®3783	Buck, Boost, Buck/Boost Mode	3000:1 PWM	3 to 36	40	Ext. FET	4mm x 5mm DFN-16, TSSOP-16E

*Actual output current will depend on V_{IN}, V_{OUT} and topology.

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LINEAR TECHNOLOGY

Simple toggle circuits illustrate low power-MOSFET leakage

Tom Bruhns, Mukilteo, WA

The novelty circuit in **Figure 1** illustrates the extremely low gate-leakage current typical of modern power MOSFETs. You can find parts that, in a moderately dry environment, will hold their state for days at a time. In operation, if MOSFET Q_1 is off, the load—perhaps a lamp or a buzzer—pulls Q_1's drain to nearly the 12V-dc power-supply voltage. R_2 charges C_1 to practically the same voltage. If you tap momentary-contact switch S_1, C_2 and the gate of Q_1 charge to about 99% of C_1's initial voltage, assuming that the tap is short enough that C_1 doesn't discharge significantly back through R_2 to the drain of Q_1, which is now at a low voltage. During the next couple of seconds, C_1 discharges through R_2 toward the new drain voltage of Q_1, which now conducts current through load resistor R_1.

In the construction of the circuit, you must ensure extremely low leakage from the MOSFET's gate node. You can omit C_2 if you use a switch with essentially no leakage, and you may find that the gate capacitance of Q_1 is enough and that the leakage is low enough that days pass before the output changes significantly. If you'd like to ensure a longer hold time, you can increase the value of C_2. A modern polypropylene capacitor should have a self-discharge time constant measured in years if you keep it clean, dry, and not too far above room temperature. If you increase C_2, proportionately increase C_1 and decrease R_2 to maintain an R_2C_1 time constant of about half a second.

Another curious behavior of this novelty circuit occurs if you hold down S_1 for a few seconds. The gate of Q_1 then goes to a voltage slightly higher than the gate's threshold voltage for Q_1. If, for example, the power supply is 6V and the load is a 6V incandescent lamp and Q_1's gate threshold is approximately 3V, the lamp will light dimly. When you release the switch, because a typical power MOSFET has a high rate of drain-current change with gate-voltage change—that is, transconductance—you can observe

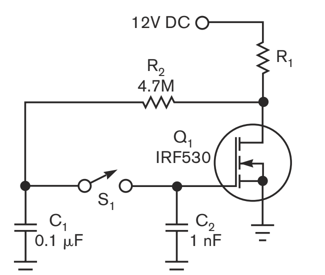


Figure 1 This "toggle" circuit demonstrates the low gate leakage of modern power MOSFETs.

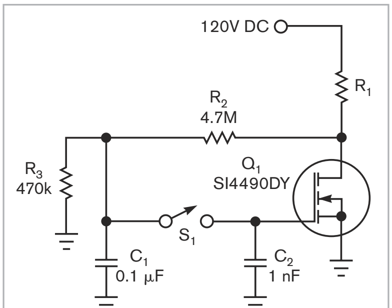
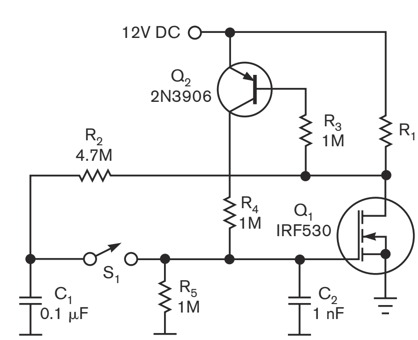


Figure 2 This circuit can control higher voltages because it supplements R_2 with a resistor to ground to form a voltage divider, ensuring that C_1 doesn't charge to a voltage that would destroy the gate of Q_1.



NOTE: LOADS AS LARGE AS A FEW AMPS ARE POSSIBLE WITH THE RIGHT POWER MOSFET.

Figure 3 This version of the toggle circuit indefinitely holds a state.

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the slow change in gate voltage as a change in lamp brightness. Any leakage is inside and external to Q_1. You may be able to detect a change in lamp brightness within a few seconds. But, even if you don't notice it, some change of voltage will occur. If you tap S_1 several times at intervals of a few seconds, the lamp will soon toggle between full brightness and fully off.

To use the circuit to control higher voltages, you can supplement R_2 with a resistor to ground to form a voltage divider to ensure that C_1 doesn't charge to a voltage that would destroy the gate of Q_1 (**Figure 2**). For a more practical toggle circuit that will indefinitely hold a state, you can add a transistor and some resistors (**Figure 3**).

If Q_1 is on and powers the load, then Q_2 is also on, holding Q_1's gate on at about half the power-supply voltage because of the voltage-divider action of R_4 and R_5. Tapping S_1 toggles the output as before, and, with Q_1 off, Q_2 is also off, allowing R_5 to hold Q_1's gate near ground potential. EDN

Circuit adds functions to a monostable multivibrator

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Nuclear Research Laboratory, Bhabha Atomic Research Centre, Kashmir, India

Gate generation is often an inevitable step in digital-signal processing. Invariably, the gate generation during event processing in a digital system uses the input trigger of a monostable multivibrator. The values of the RC (resistance-capacitance) components within the manufacturer-supplied parameters determine the gate width of the output pulse of the monostable multivibrator. The monostable multivibrator generates only one-shots for each input trigger during event processing.

However, you can enhance the functional capability of gate generation of a monostable multivibrator with modifications in its input-trigger circuitry to generate any number of output-gate pulses for each single-input triggering. You can exploit the resultant circuit to generate a fixed number of repetitive gate pulses with a single-input trigger by incorporating a counter with the circuit to keep track of the gate generation. The monostable multivibrator becomes inactive as soon as it generates the requisite number of gates.

Figure 1 shows modifications to a monostable multivibrator that allow it to repetitively generate 63 gate pulses with one trigger. The RC components determine a gate width of 5 to 75 μsec. However, this design has a preset gate width of 20 μsec to give a total time

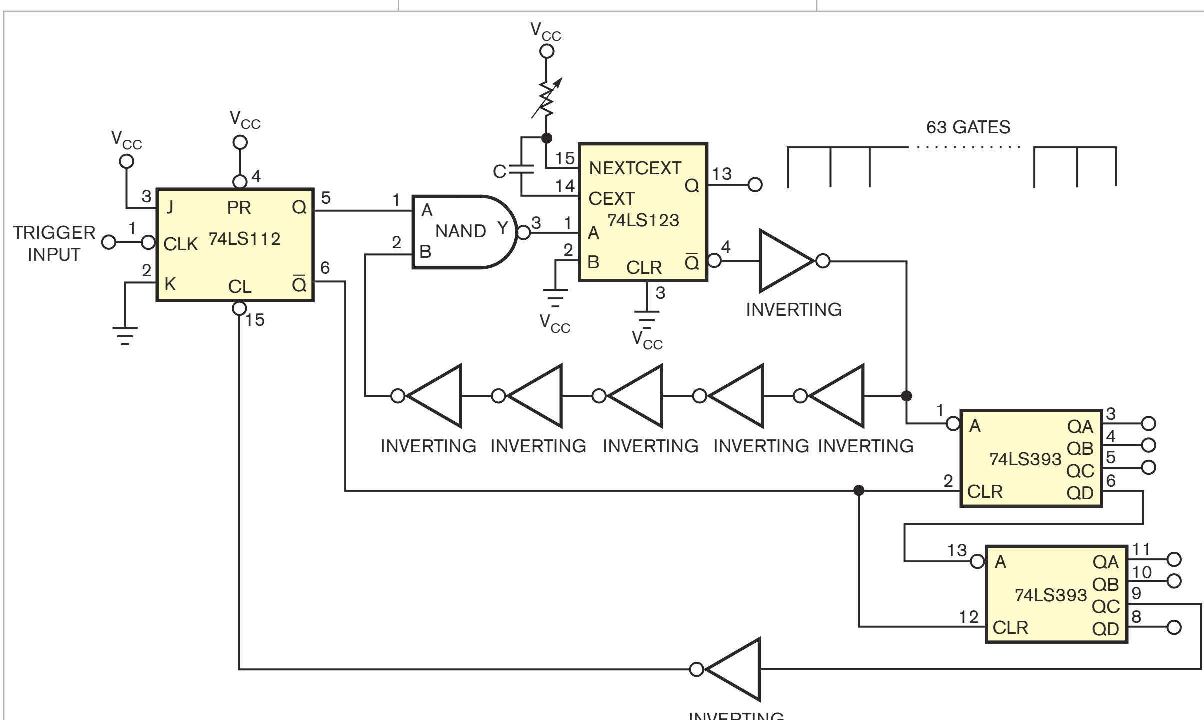

Figure 1 By adding counters and an oscillator to the output of a monostable multivibrator, you can generate any number of output-gate pulses.

LINEAR TECHNOLOGY
DESIGN NOTES

A Complete Compact APD Bias Solution for a 10Gbits/s GPON System – Design Note 447

Xin Qi

Introduction

Avalanche photo diode (APD) receiver modules are widely used in fiber optic communication systems. An APD module contains the APD and a signal conditioning amplifier, but is not completely self contained. It still requires significant support circuitry including a high voltage, low noise power supply and a precision current monitor to indicate the signal strength. The challenge is squeezing this support circuitry into applications with limited board space. The LT®3482 addresses this challenge by integrating a monolithic DC/DC step-up converter and an accurate current monitor. The LT3482 can support up to a 90V APD bias voltage, and the current monitor provides better than 10% accuracy over four decades of dynamic range (250nA to 2.5mA).

Recent communication design efforts increasingly focus on the 10Gbits/s GPON system, which demands that the transient response of the APD current monitor is less than 100ns for an input current step of two decades of magnitude. A simple compact circuit using the LT3482 is fast enough to meet this challenging requirement.

An APD Bias Topology with Fast Current Monitor Transient Response

The circuit in Figure 1 shows the LT3482 configured to produce an output voltage ranging from 20V to 45V from a 5V source—capable of delivering up to 2mA of load current. Its operation is straightforward. The LT3482 contains a 48V, 260mA internal switch, which boosts V_{OUT1} to one-half the APD output voltage level. This voltage is doubled through an internal charge pump to generate V_{OUT2}. All boost and charge pump diodes are integrated. V_{OUT2} is regulated by the internal voltage reference and the resistor divider made up of R3 and R4. At this point, V_{OUT2} goes through the integrated high side current monitor (MONIN), which produces a current proportional to the APD current at the MON pin.

The output voltage is available for the APD at the APD pin. The CTRL pin serves to override the internal reference. By tying this pin above 1.25V, the output voltage is regulated with the feedback at 1.25V. By externally setting the CTRL pin to a lower voltage, the feedback and the output voltage follow accordingly.

The $\overline{SHDN}$ pin not only enables the converter when 1.5V or higher is applied, but also provides a soft-start function to control the slew rate of the switch current, thereby minimizing inrush current. The switching frequency can be set to 650kHz or 1.1MHz by tying the FSET pin to ground or to V_{IN}, respectively. Fixed frequency operation allows for an output ripple that is predictable and easier to filter.

To achieve fast transient response, any time-delay component along the signal path should be minimized. Figure 1 shows an APD bias topology with fast current monitor transient response. Unlike the ultralow noise topology

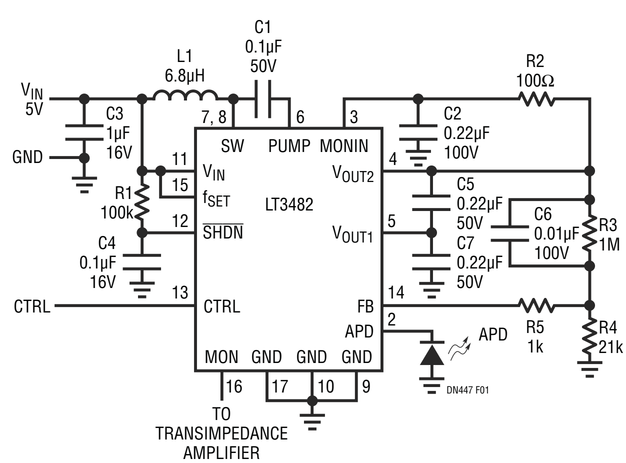

Figure 1. Fast Current Monitor Transient Response ADP Bias Topology

with a filter capacitor at the APD pin, the filter capacitor is moved to the MONIN pin of the LT3482. The output sourcing current from the MON pin is directly fed into a transimpendance amplifier.

A typical measured current monitor transient response consists of the signal generation delay at the APD pin, the built-in current monitor response time and the measurement delay at the MON pin. Thus, every effort should be made to reduce signal generation and the measurement delays.

Figure 2 shows the measurement setup. An NPN transistor in common base configuration is used to generate the fast current step representing the APD load. A function generator provides two negative bias voltages at the PWM node that result in two decades current step at the APD pin. At the MON pin, a wideband transimpedence amplifier is implemented using the LT1815. Operating in a shunt configuration, the amplifier buffers the MON output current and dramatically reduces the effective output impedance at the OUT node. Note that there is an inversion and a DC offset present when this measurment technique is used. A regular oscilloscope probe can then be used to capture the fast transient response at the OUT node.

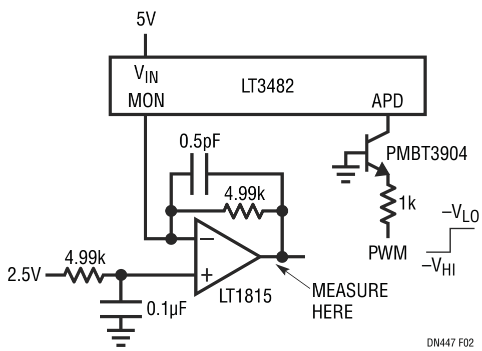

Figure 2. Fast Transient Response Measurement Setup

Figures 3 and 4 show the measured input signal rising transient response and the measured input signal falling transient response, respectively, where the input current levels are 10µA and 1mA. The PWM input signal levels are selected based on the static measurement results. The APD current is accurately mirrored by the LT3482 with an attenuation of five and sourced from the MON pin. With a 2.5V reference voltage, the OUT node voltage swings between 1.5V (= 2.5V – 1mA/5 • 4.99k) and 2.49V (= 2.5V – 10µA/5 • 4.99k) responding to the input signal step. The measurements demonstrate less than 50ns transient response time, which exceeds the stringent speed demand of the 10Gbits/s GPON system.

Conclusion

The LT3482 is a complete space-saving solution to APD receiver module support circuitry design. It offers more than just low bias noise and compact solution size; it also features UltraFast™ current monitor transient speed that addresses the challenges presented in the 10Gbits/s GPON system.

UltraFast is a trademark of Linear Technology Corporation.

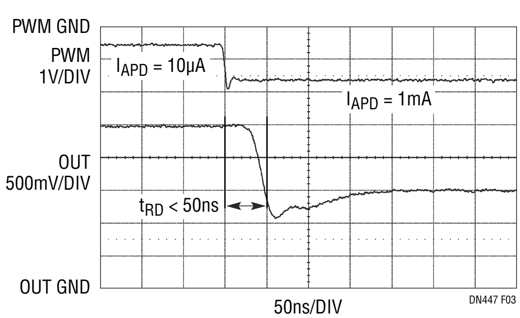

Figure 3. Transient Response on Input Signal Rising Edge (10µA to 1mA)

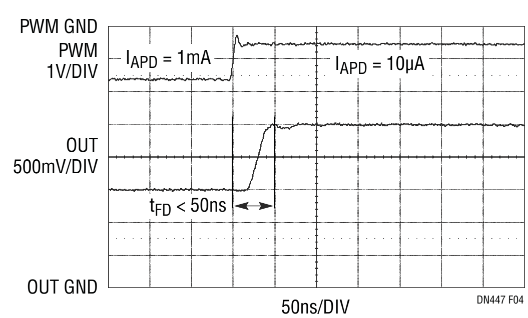

Figure 4. Transient Response on Input Signal Falling Edge (1mA to 10µA)

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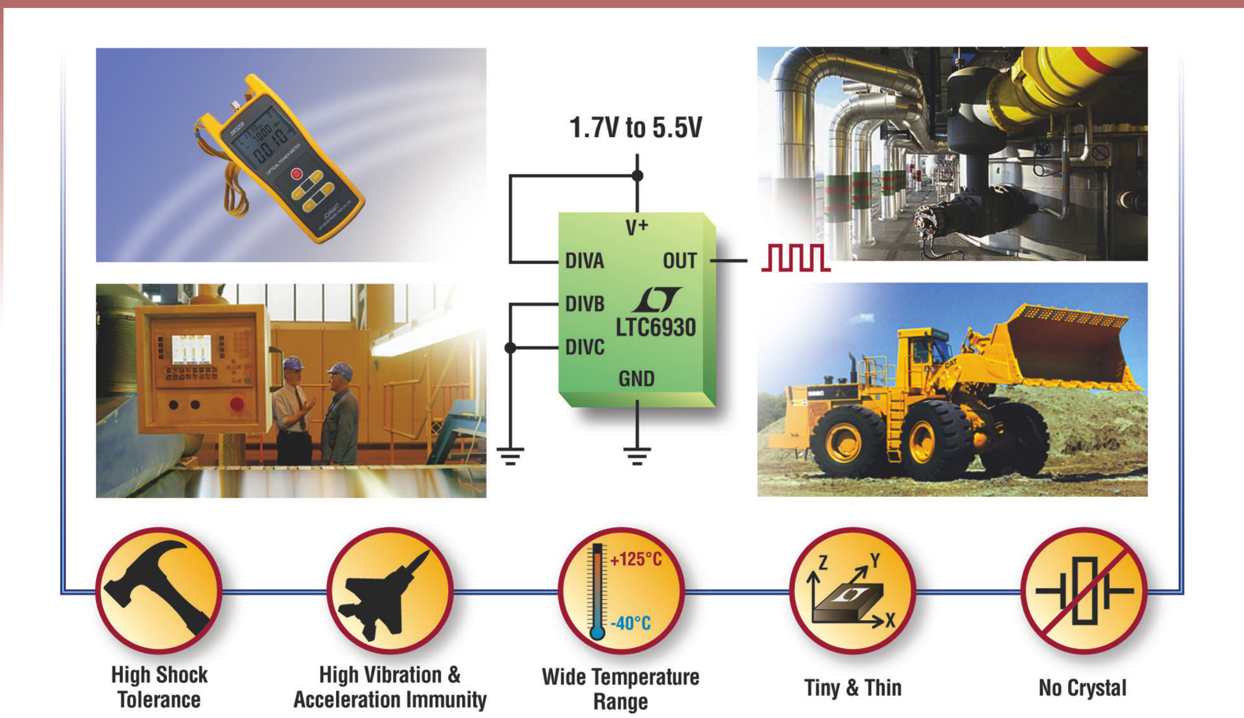

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interval of 1260 μsec. When the input-trigger pulse goes to the active low, Pin 1, of the JK 74LS112 flip-flop, the falling edge of the input-trigger pulse activates the flip-flop to set Q. Because the default condition of Pin 2 of the NAND gate is at a high level, the transition at the output pin, Pin 3, of the NAND gate passes on to the active-low input of the monostable multivibrator at Pin 1. The falling edge of the output pulse of the NAND gate triggers the monostable multivibrator to generate the first gate pulse of predefined gate width.

Subsequently, when the Q output pulse of the monostable multivibrator makes a transition from high to low, the rising edge of the complementary output pulse of the monostable multivibrator at $\overline{Q}$, Pin 4, connects back to the two-input NAND gate. Through a series of inverter retriggers, the monostable multivibrator again generates the next gate pulse. The gate generation can continue indefinitely. However, the $\overline{Q}$ output after inversion also feeds into two 74LS393 hex counters. The two hex counters cascade together to count the 63 gate pulses. As soon as the circuit counts the requisite number of gate pulses, Pin 9 of the hex counter goes high and, after inversion, clears the active state of the JK flip-flop.

The two-input NAND gate's Pin 1 also goes to a low level and disables the flip-flop, preventing the feedback rising-edge transition of the $\overline{Q}$ of the monostable multivibrator from again passing on to the trigger input—Pin 1 of the monostable multivibrator. So, the trigger to the monostable multivibrator and further gate generation stop (**references 1 and 2**).EDN

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Piezoelectric driver finds buzzer's resonant frequency

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Piezoelectric buzzers find wide use as audible-signal generators because of their low power consumption and clear, penetrating sound. An external driver or a self-driven circuit that oscillates at the resonant frequency of the piezoelectric element can drive these buzzers. A piezoelectric element produces the maximum sound output at its resonant frequency. However, the resonant frequency of a piezoelectric element can have a tolerance as great as ±15%. An external driver tuned to the nominal resonant frequency is therefore likely to miss the actual resonance point. This Design Idea externally drives a piezoelectric element and automatically finds its actual resonant frequency.

The basis for operation is the following principle: When you apply an alternating voltage to the terminals of a piezoelectric element, the element will begin to vibrate. If you remove the excitation, vibrations will continue in a damped manner before they cease altogether. These residual vibrations will cause damped oscillations at the terminals of the piezoelectric element. If the excitation is close to the resonant frequency, the vibrations will be stronger and the residual oscillations will last

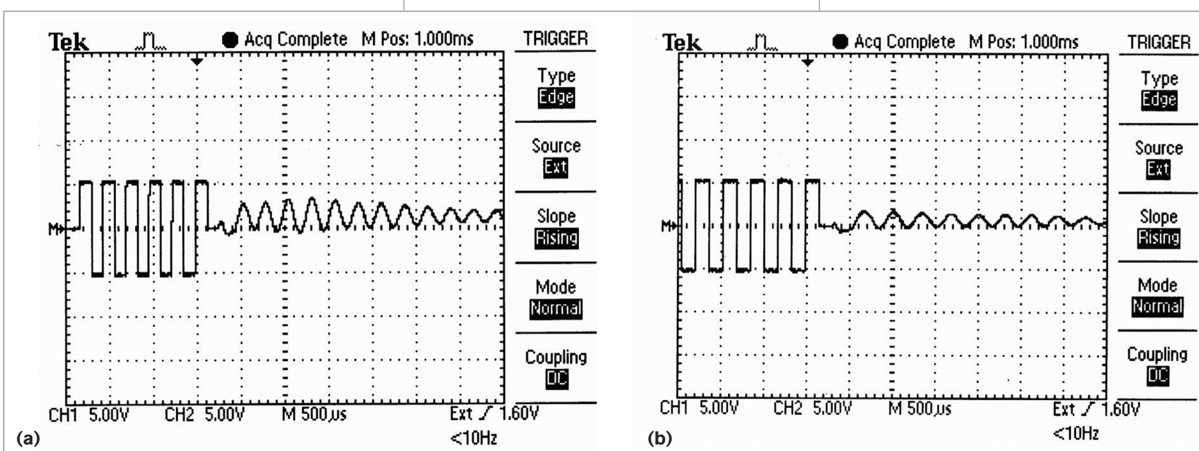

Figure1 At a frequency of 4 kHz, which is closer to the resonant frequency, residual oscillations last longer (a) than the resonant frequency with 3.2 kHz (b).

longer (**Figure 1**). You can determine the actual resonant frequency by trying all the frequencies around the nominal resonant frequency and comparing the duration of residual oscillations.

In this design, a Microchip (www.microchip.com) PIC18F452 microcontroller drives a piezoelectric element through its I/O pins, RB4 and RB3 (**Figure 2**). Initially setting RB3 to zero and RB4 to one and toggling them after each half-period generates an alternating piezoelectric voltage (V_P) with a 0V-dc bias. After applying 10 cycles, RB3 is kept low, and

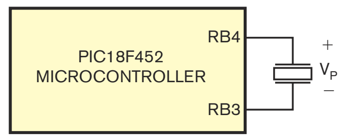

Figure 2 A PIC18F452 microcontroller first drives the piezoelectric buzzer at a programmed frequency and then configures one of its pins as an input to count the residual oscillations.

RB4 is made an input to count the low-to-high and high-to-low transitions of V_P. Enabling the "interrupt-on-port-change" feature of Port B for 10 msec and incrementing a counter in the interrupt-service routine counts the transition of the piezoelectric voltage. **Listing 1**, which is available in the Web version of this Design Idea at www.edn.com/080807di1, demonstrates this feature. The program repeats these steps for all frequencies of interest and identifies the frequency corresponding to the maximum number of transitions at the resonant frequency. You can easily expand the idea for the case of multiple resonant frequencies. EDN

Low-cost digital DAC provides digital three-phase-waveform synthesis

SA González, Universidad de Mar de Plata, Argentina,
and R García-Gil, J Castelló, and JM Espí, Universidad de Valencia, Spain

Many applications involve the digital synthesis of three-phase sinusoidal waveforms, such as ac-motor drives, active power filters, and grid-voltage synchronizers, that use a microcontroller or a DSP for digital control. You can perform this synthesis by using conventional analog techniques (**Reference 1**) or DDS (direct digital synthesis). Digital techniques provide higher stability and the ability to incorporate frequency, phase, and amplitude adjustments. For applications requiring 16-bit or higher-resolution, three-phase-signal synthesis, DDS involves the use of a microprocessor or a DSP to interface multiple DACs. This approach uses not only a lot of devices, but also supporting components and board space. Although one device can have multiple-output serial-controlled DACs with four, eight, 32, or more

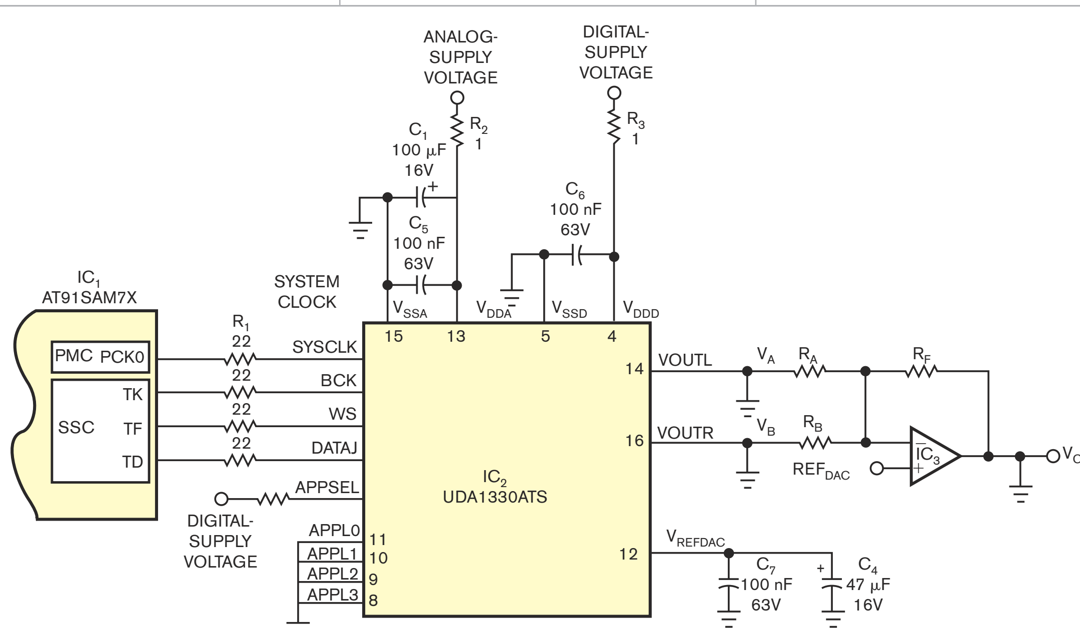

Figure 1 This scheme implements three-phase DDS (direct digital synthesis) with few components. The code in the ARM processor provides the ability to incorporate arbitrary frequency, phase, and amplitude adjustments with 16-, 18-, or 20-bit resolution.

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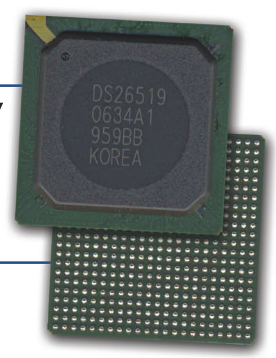

Part	Power Consumption (typ, W)**	Port Count	Pin Count	Package	Price† ($)
DS26519	2.4	16	484	484-HSBGA	57.90
DS26518	1.2	8	256	256-CSBGA	33.60
DS26514*	0.75	4	256	256-CSBGA	19.80

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†25k-up recommended resale. Prices provided are for design guidance and are FOB USA. International prices will differ due to local duties, taxes, and exchange rates. Not all packages are offered in 1k increments, and some may require minimum order quantities.

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channels, the DACs provide few bits at the expense of the number of channels. Hence, using multiple-output DACs is an unappealing approach.

Alternatively, you can use shift registers or switched-capacitor filters, but this approach also involves a high parts count, and the lack of phase and amplitude adjustment makes this method inappropriate for high-resolution DDS (**Reference 2**). In contrast, stereo DACs are readily available. Their widespread use has produced low-cost, high-quality components. For example, the NXP UDA1330ATS has an I^{2}S-serial data-format interface; word lengths of 16, 18, and 20 bits; and sampling frequencies of 8 to 55 kHz (**Reference 3**). These features make the DACs attractive for three-phase DDS with few components.

This Design Idea implements DDS techniques using an ARM microcontroller, IC_1; one stereo-DAC, IC_2; and one op amp, IC_3 (**Figure 1**). The ARM AT91SAM7X256 code in **Listing 1**, available in the Web version of this Design Idea at www.edn.com/080807di2, generates a table containing the cosine function of the desired resolution and length. The table produces $\cos(\alpha+2/3\pi)$ and $\cos(\alpha-2/3\pi)$. The ARM microcontroller sends the data using I^{2}S-serial format by using interrupts attaching the ISR (interrupt-service routine) whenever the output buffer is empty. **Listing 2**, also in the Web version of this article, shows how to achieve an ISR to send the data. IC_2 provides voltage outputs V_A and V_B, which are two of the three signals for a maximum amplitude of 5V p-p, but with an offset of 2.5V. You can derive the third channel as a function of the other channels. You can easily implement this operation using a single inverting, summing op amp, IC_3, and the 2.5V DAC reference for canceling the offset. In this case, $R_F=R_A=R_B=10\ k\Omega$ for obtaining unity gain, and you could add a potentiometer in the inverting pin for an exact offset cancellation if the resistors don't match exactly.

Figure 2 shows the synthesis of the three-phase waveforms. For further explanation and to access the **references** to this article, go to www.edn.com/080807di2. EDN

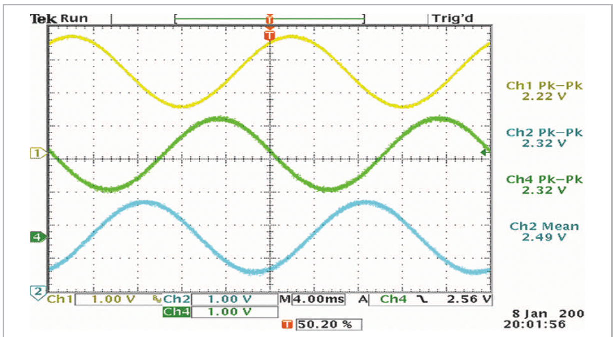

Figure 2 Traces 1 and 2 show the voltage outputs from the DAC. Trace 4 is the third channel that an inverting, summing op amp provides.

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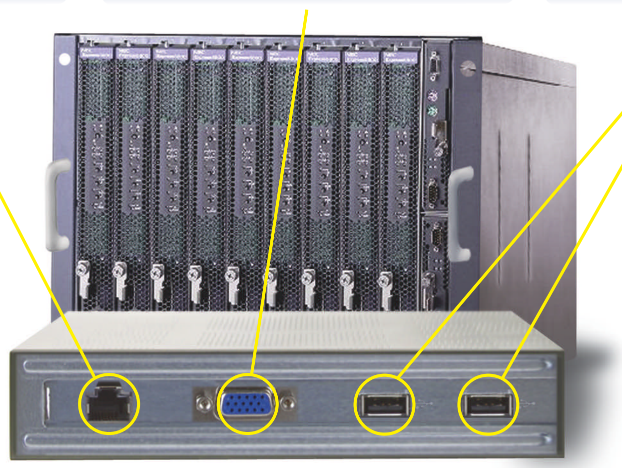

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MAX4887	RGB triple video switch
MAX4929E	2:1/1:2 HDMI control switch
USB	
MAX4899AE/MAX4899E	Fault-tolerant, Hi-Speed USB 3:1/4:1 muxes
MAX4999	Hi-Speed USB 8:1 mux (NEW)
MAX4906EF/MAX4906F/MAX4907/MAX4907F	Hi-Speed USB switches

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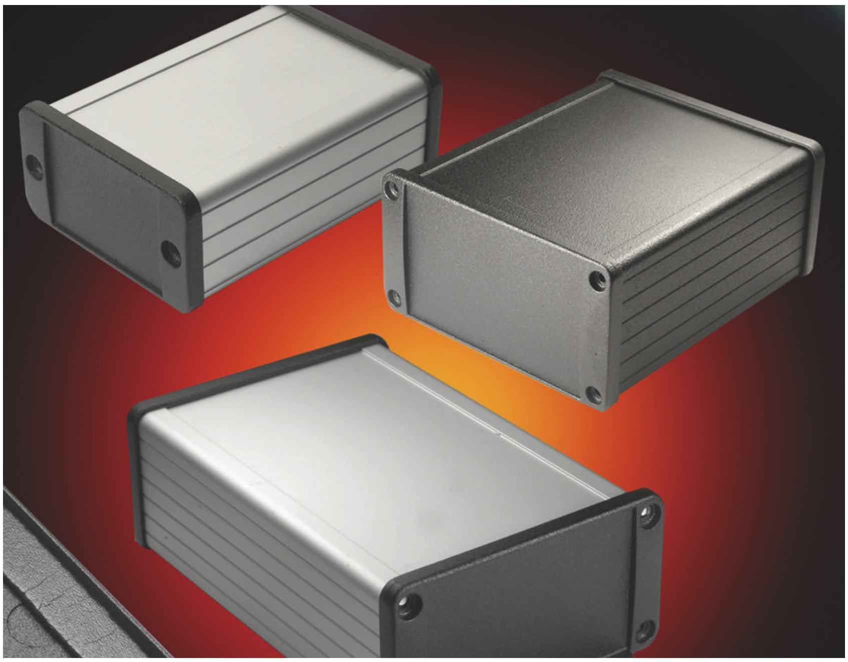

IP65 sealed enclosures target dusty, wet environments

The 1457 series IP65 sealed, die-cast-aluminum end panels is the latest addition to the vendor's family of extruded-aluminum, small enclosures. The 1457 series suits dusty, wet environments. The enclosures are available with or without integral flanges, allowing you to mount them on external surfaces. The devices house PCBs and allow horizontal mounting into internal slots in the body of the case. The devices also house small electronic, electrical, or pneumatic components. O-ring-screw seals and closed-cell polyethylene-sealing gaskets provide sealing. The six sizes range from 80×59×31 mm to 160×104×55 mm, and the largest unit accepts a 160×100-mm standard Eurocard. Prices for the enclosures range from $16.40 to $26.41 (100).

Hammond Manufacturing, www.hammondmfg.com

Remote temperature- and humidity-monitoring system alerts user by e-mail

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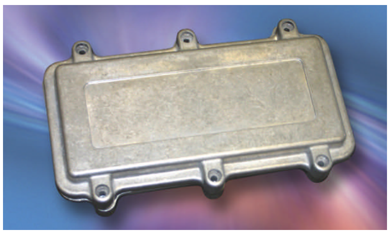
ture-and-humidity modules using standard intranet cables. You can place the sensors as far as 250 feet away from the hub. The Data Center System service costs $29.95 for six months; the DLP-UT1 sensor and the DLP-UTH8 hub temperature- and humidity-acquisition products cost $29.95 each.
DLP Design, www.dlpdesign.com



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Bud Industries, www.budind.com

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Orion Fans, www.orionfans.com

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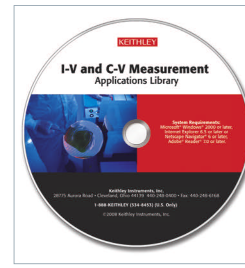

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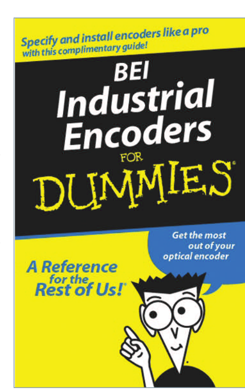

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Dumping the noise

I recently completed designing an ultrasonic receiver that accepted signals in the 100- to 200-kHz band, downconverted the signal to an audio band, digitized it, and sent it to a remote computer. The computer provided an audio output and could display an FFT (fast-Fourier-transform) spectral analysis on the received signal. The receiver was closely integrated with a microcontroller that handled the serial communications and sent the local oscillator plus gain commands to the receiver.

I closely modeled this receiver after a successful through-hole design that included various ICs, some inductors, and the usual resistors and ceramic capacitors. The new receiver used surface-mount components on a small PCB (printed-circuit board) that plugged into a female header on the microcontroller board. I was well-aware that microcontroller circuits could generate a lot of electrical noise, but the position of other elements constrained the location of the receiver. On firing up the receiver for the first time, I observed considerable noise, which, although not unexpected, was nevertheless disappointing. To facilitate test and evaluation, I built a small test board that had the female header; a ribbon cable connected the test board to the microcontroller board. And, by moving the receiver around the microcontroller circuits, I found that the noise-entry point was through the inductors. I changed the inductors to the shielded variety, but the approach yielded no improvement. Although the inductors were part of a required passive-filter circuit, the inescapable conclusion was that they had to go. In the final design, an active filter replaced this passive filter.

But another problem now popped up: When the receiver was on the ribbon cable, I occasionally knocked the board against the hard table surface, which produced an audible click in the sound output when the board hit the table. This event blew me away. The components on my receiver board were totally solid-state, and such a thing should never happen. I immediately suspected a cold solder joint and sent the board back to the assembly area, where workers inspected it and reheated the suspicious joints—but to no avail. I then pulled out the previous through-hole receiver and banged away with some vigor against the table, but that design was as quiet as a mouse.

Now, I commenced thinking about how the construction of the various components might result in microphonics, and this idea brought up a dim memory that ceramic capacitors were made from barium-titanate. I knew that barium-titanate is a piezoelectric material, which kicked my suspicions up a notch. A Web search with piezoelectric and ceramic capacitors together in the search phrase generated several articles on the effect (www.atceramics.com).

So, there it was: The problem definitely arose from the ceramic capacitors. The through-hole board was not microphonic because the capacitor leads absorbed the shock. But a PCB with surface-mount components is a relatively rigid structure able to pass a shock wave directly to the interior of the piezoelectric capacitor, thereby inducing a small electric signal. For the final iteration, I replaced all ceramic capacitors with film ones, removed all components from the bottom of the board, and installed an unbroken, edge-to-edge ground plane. I removed the inductors and covered the front-end circuits with a machined aluminum enclosure electrically connected to the ground plane. Now, I had a receiver that operated magnificently. EDN

Jim Christensen is an electronics engineer at Kris Design Services. Like him, you can share your Tales from the Cube and receive $200. Contact edn.editor@reedbusiness.com.

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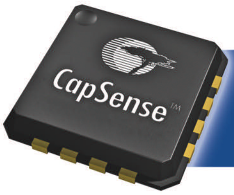

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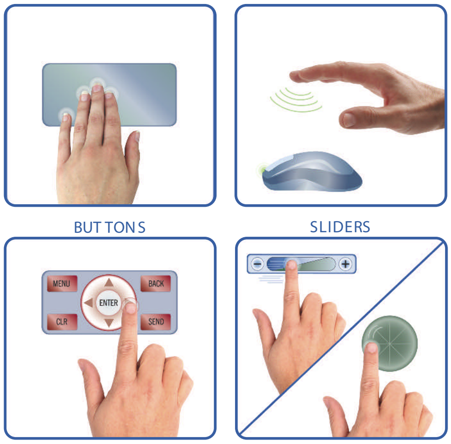

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